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The INSTITUTION *of* PRODUCTION ENGINEERS

JOURNAL

(*September* 1944, *Vol. XXIII, No. 9, Ed. A*)

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by W. L. Sims, A.M.I.E.E., A.M.I.Mech.E.

SOME APPLICATIONS OF ELECTRIC POWER TO MACHINE TOOLS
by C. Hayward, Grad.I.P.E., A.M.I.Mech.E.

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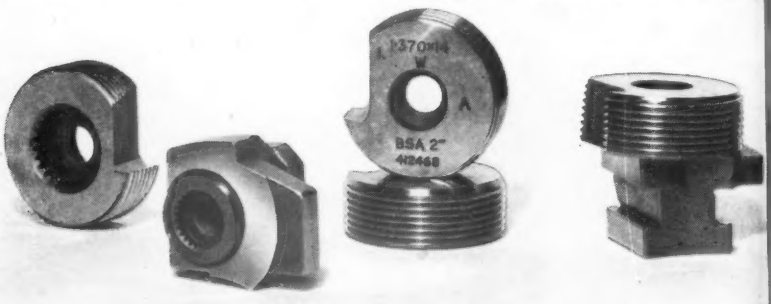

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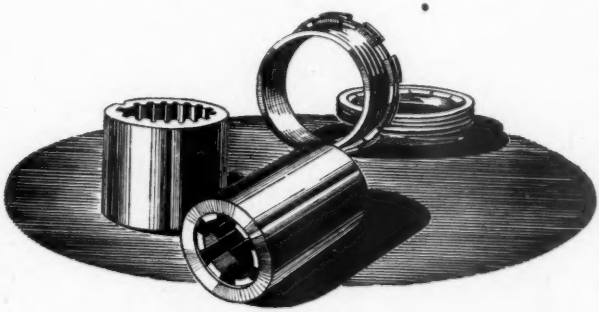

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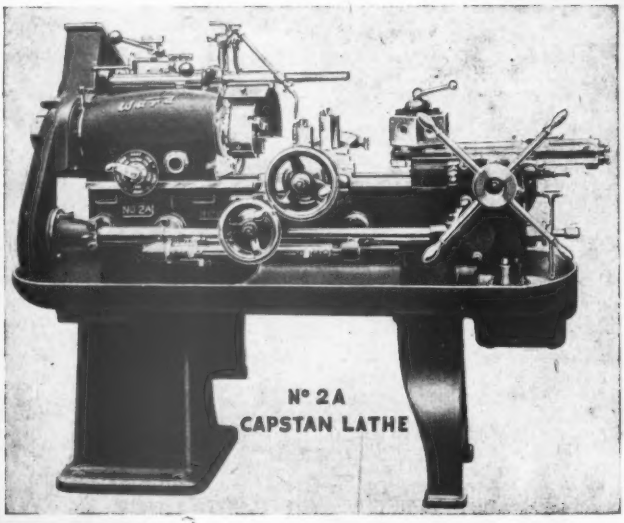

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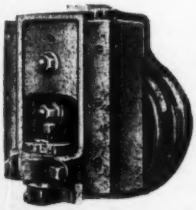

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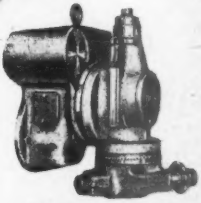

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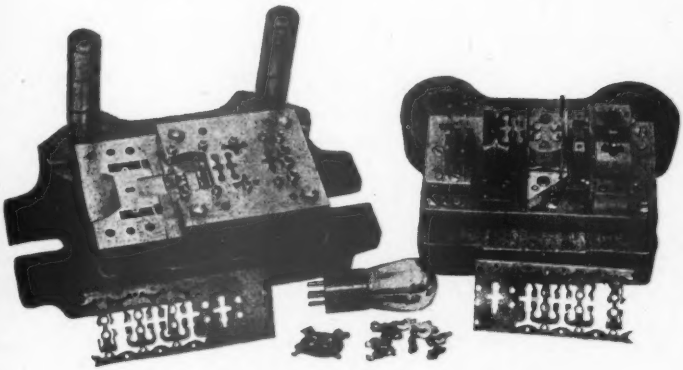

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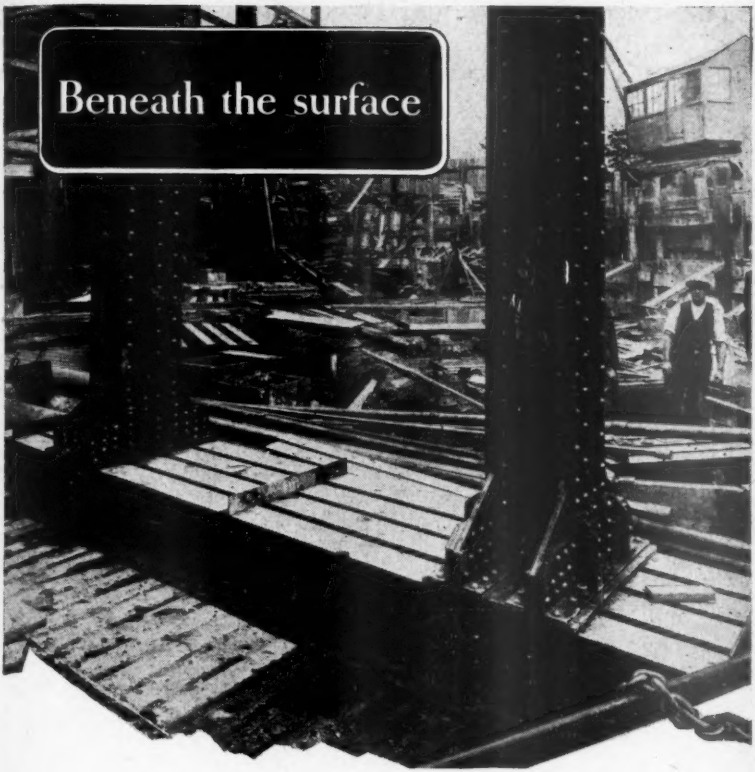

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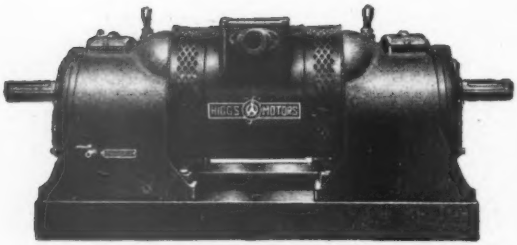

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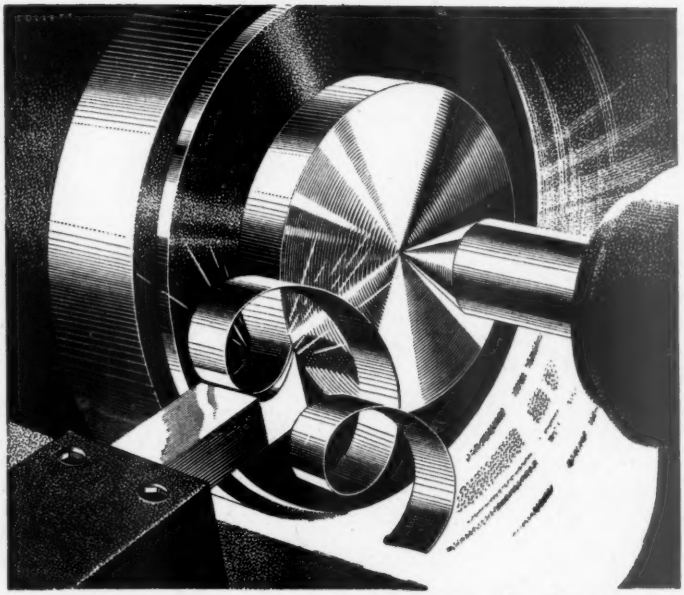

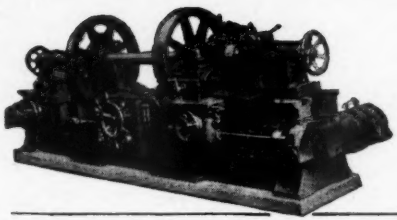

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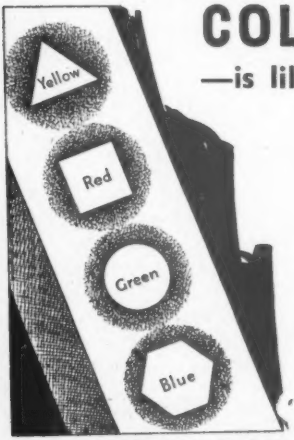

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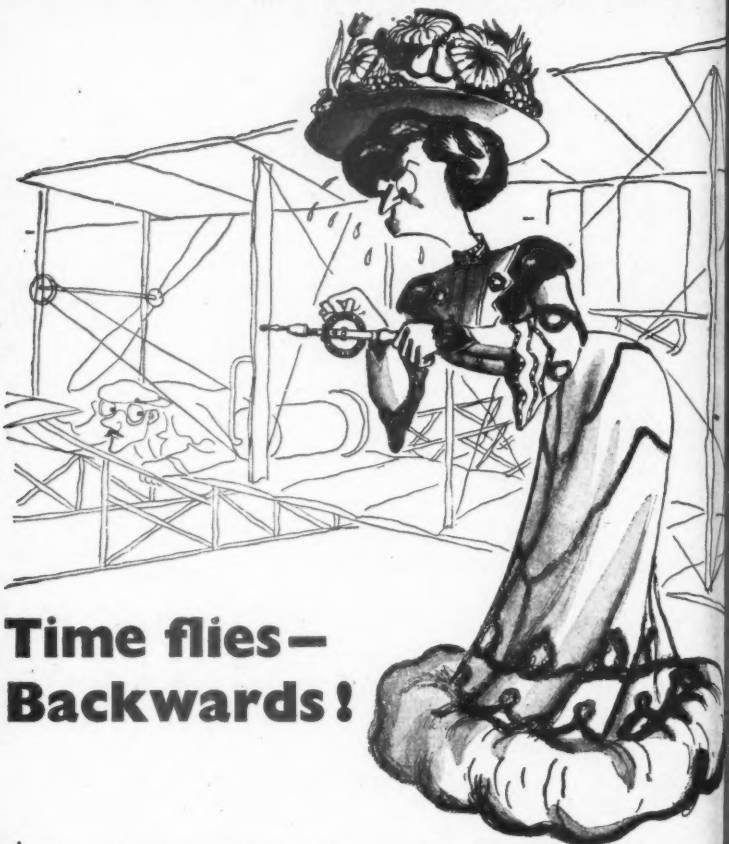

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A man we know has worked out by means of a slide-rule and a bit of snooping 351,429 man-hours were lost to industry on February 17th, 1944 by drilling holes hand drills instead of Desoutter power drills. He says that the result of this immense of time was that when the workers came to work next day it was *really* February 1903. After bit of a pause while our eyes stopped rolling, we said we thought there a catch in it. We said wouldn't it be February 18th, 1985. Like British Summer T first you put it on and then you take it off. He said, no, it was 1903 like he said and w terrible waste of time. He said the British were always getting ready for the previou and this proved it. Well, we wouldn't stand for that so we slung him out and his rule after him. But it's a shaking sort of a thought, isn't it? And nothing you c about it because Desoutter Tools weren't invented in 1903.

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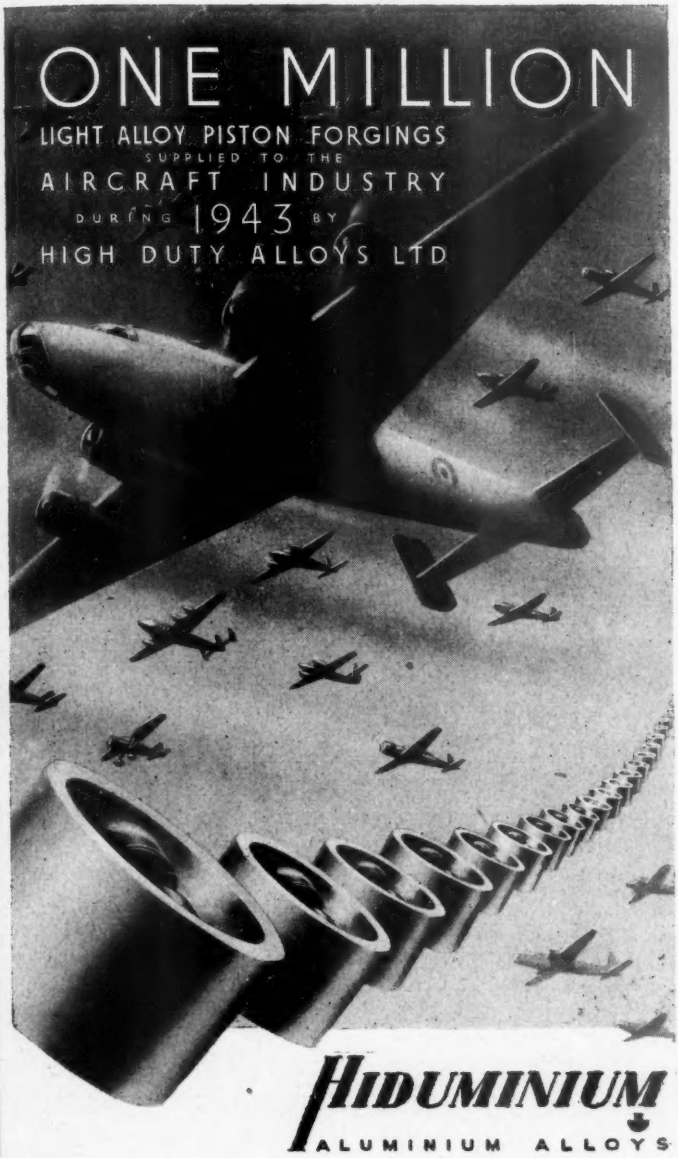
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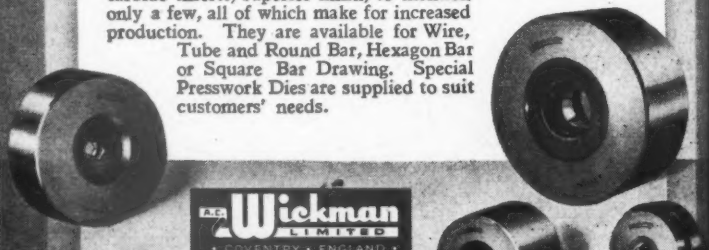

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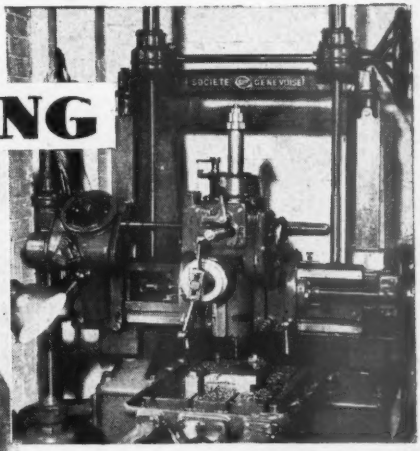

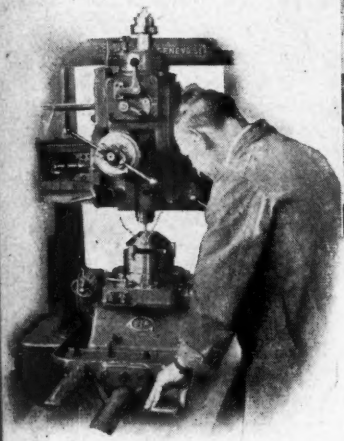

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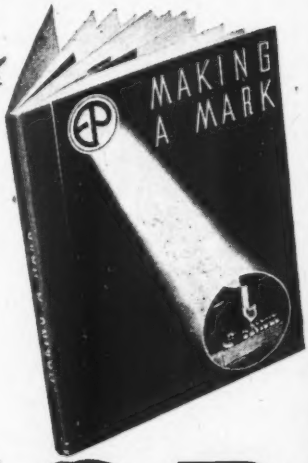

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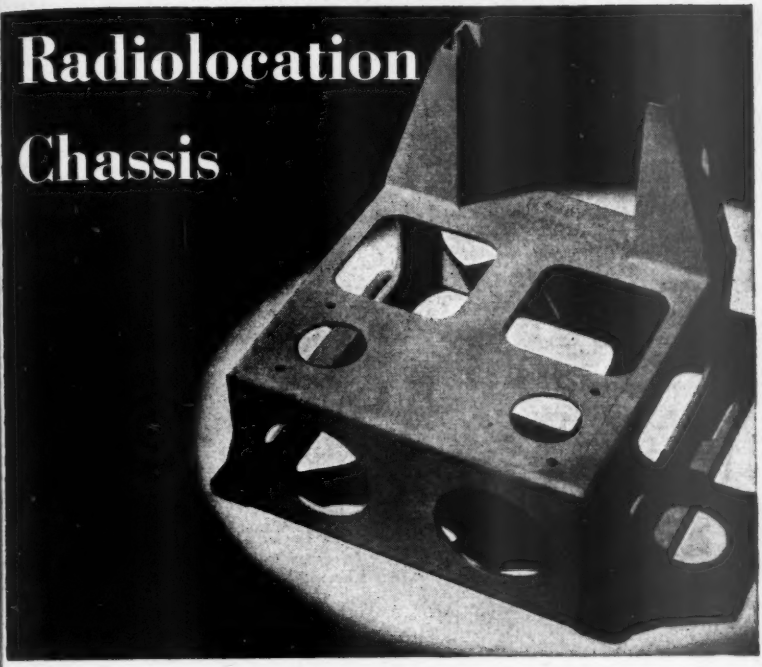

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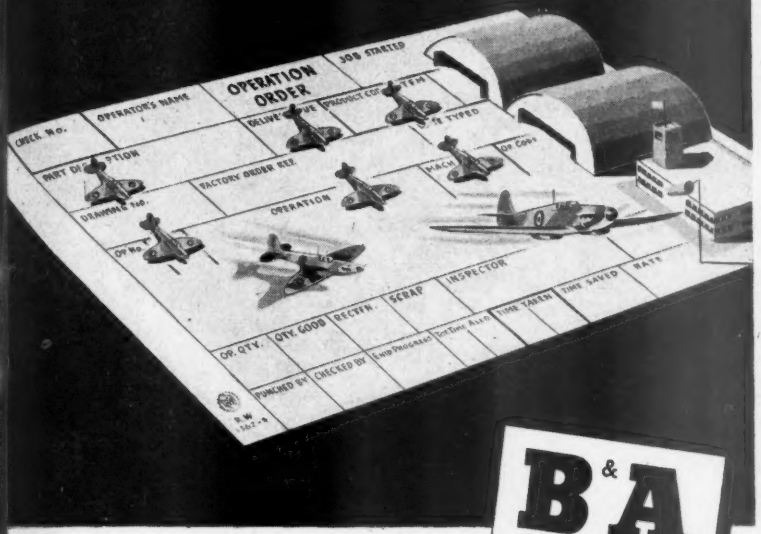

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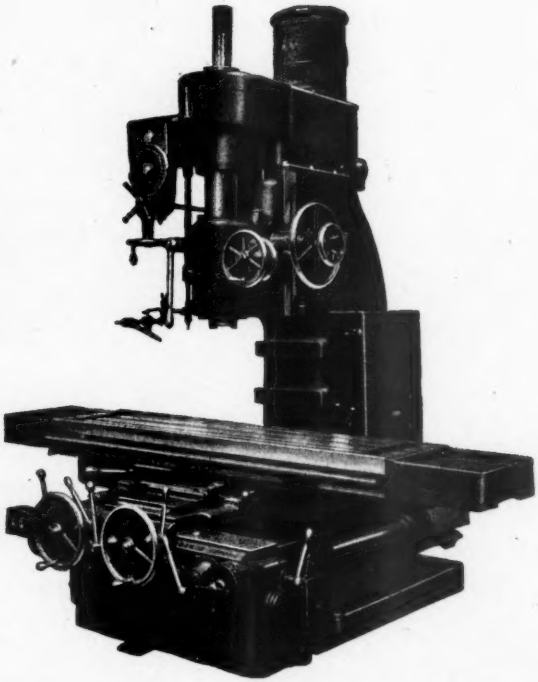

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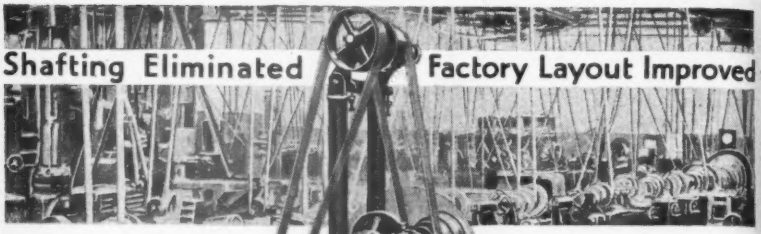

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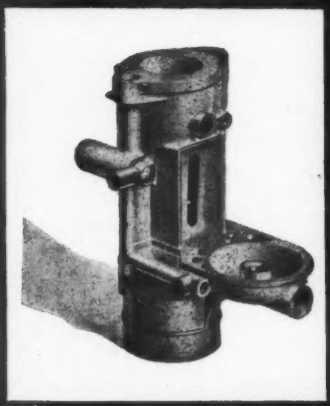

★ *Write for Treatise on Die Castings*

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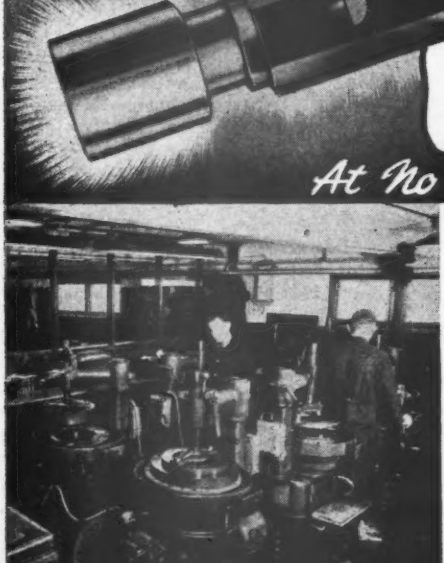

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1943-44

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INSTITUTION NOTES

September 1944

Annual General Meeting—Official Notice.

NOTICE IS HEREBY GIVEN that the Annual General Meeting of the Institution will be held on Friday, 27th October, 1944, at the Institution of Civil Engineers, Great George Street, London, S.W.1., at 3 p.m.

Agenda.

1. Notice convening Meeting.
2. Minutes of previous Annual General Meeting.
3. Report on Election of President and Members of Council.
4. Annual Report of the Council.
   Annual Report of the Research Committee, and Annual Accounts for the year ended 30th June, 1944.
5. Election of Auditors for 1944-45.
6. Votes of thanks.

BY ORDER OF THE COUNCIL.

10, Seymour Street,
London, W.1.

K. G. FENELON,
General Secretary.

October Meetings.

5th Leicester Section. A meeting will be held at the Leicester College of Technology at 7 p.m. when R. C. Shuster, M.I.P.E. will lecture on " Care and Maintenance of machine tools."

9th Coventry Graduate Section. A meeting will be held at the Coventry Technical College at 6-30 p.m. when two short papers will be read : " Some Aspects of Night Shift Supervision " by D. H. Morgan, Grad.I.P.E., and '" General thoughts on Engineering Metallurgy."

11th Sheffield Section. A meeting will be held at the Royal Victoria Station Hotel at 6-30 p.m. when Dr. A. P. Fleming, C.B.E., will lecture on " Some Post War Industrial Problems."

12th Manchester Section. A meeting will be held at the College of Technology at 7-15 p.m. when Dr. Fenelon will lecture on " Output and Environment."

October Meetings—*continued.*

13th Manchester Section. A meeting will be held at the Mechanics Institute, Crewe at 7-15 p.m. when Dr. Fenelon will lecture on "Output and Environment."

14th Manchester Section. A meeting will be held at the Liverpool University, at 2-30 p.m. when Dr. Fenelon will lecture on "Output and Environment."

14th Yorkshire Section. A meeting will be held at the Hotel Metropole, Leeds, at 2-30 p.m., when H. C. Newell, M.I.P.E., M.I.Mech.E., will lecture on "Training of the Young Production Engineer."

18th Birmingham Section. A meeting will be held at the James Watt Memorial Institute, at 7 p.m. when Dr. Galloway will lecture on "Production Engineering Research."

19th North Eastern Graduate Section. A meeting will be held at Neville Hall Mining Institution, Newcastle-on-Tyne, at 6-15 p.m. when G. R. Batty, Grad.I.P.E., will lecture on "Measuring Instruments based on Levers."

21st Halifax Section. A meeting will be held at the Halifax Technical College at 2-30 p.m. when Dr. D. F. Galloway will lecture on "Production Engineering Research."

25th Manchester Section. A meeting will be held at The College of Technology at 7-15 p.m. when H. Eckersley, M.I.P.E., will lecture on "Negative Rake Milling Cutters."

24th Wolverhampton Section. A meeting will be held at Wisemore Schools, Walsall at 6-30 p.m. when Alan A. Simpson, A.M.I.P.E. will lecture on "Materials Handling Machinery."

27th Nottingham Section. A meeting will be held at Lincoln Technical College at 6-30 p.m., when F. G. Lambert, A.M.I.P.E., will lecture on "Standards in Advance of Manufacturer."

27th Coventry Section. Meeting will be held at Coventry Technical College (Room A.5.) at 6-45 p.m. when Group Captain S. A. Desmore will lecture on "Post-War Civil Aviation."

27th Eastern Counties Section. A meeting will be held at the Lecture Hall, Electric House, Ipswich at 7-0 p.m., when D. P. Ransome will lecture on "Technical Training of Production Engineers."

October Meetings—*continued.*

27th North Eastern Section. A meeting will be held at the Neville Hall Mining Institution, Newcastle-on-Tyne, at 6-15 p.m. when W. Whitworth Taylor will lecture on "High Speed Milling."

29th Luton Bedford and District Section. A meeting will be held at the Central Library Meeting Room at 10 a.m. (George Street, Luton) when J. D. Botterill will lecture on "Light Alloy Forging." Film.

October Committee Meetings, etc.

6th An Extraordinary Meeting of the Institution will be held at the Institution of Civil Engineers, Great George Street, London, S.W.1., at 11-0 a.m.

6th A meeting of the Council will be held at the Institution of Civil Engineers, Great George Street, London, S.W.1., at 11-30 a.m.

16th The Finance Committee of the Research Department will meet at Loughborough at 10-30 a.m.

16th The Management Committee will meet at Loughborough at 11-30 a.m.

20th The Finance and General Purposes Committee will meet at Institution Headquarters at 2-0 p.m.

24th The Education Committee will meet at the Queens Hotel, Birmingham at 10-0 a.m.

24th The Membership Committee will meet at the Queens Hotel, Birmingham at 12-30 a.m.

November Committee Meeting.

8th A meeting of all section secretaries with the members of the Technical and Publications Committee will be held at the Queens Hotel, Birmingham, at 12-30.

The Technical and Publications Committee meets every Wednesday at Institution Headquarters at 5-30 p.m.

Obituary.

We deeply regret to record the death of the following members of the Institution.

E. Fairbrother (*Member*), G. H. Drake (*Member*)

Contributions to the Research Department.

Since the publication of the August Journal the following contributions have been received in connection with the President's appeal on behalf of the Research Department and the Council wish to express thanks to all those concerned.

	£	s.	d.
R. Clearly, Esq.	1	0	0
Imperial Typewriter Co., Ltd.	25	0	0
The British Electrical Engineering Co., Ltd.	10	10	0
R. A. Lister, Esq.	3	3	0
William & James...	10	0	0
Maudsleys, Ltd.	10	10	0
George Adlam & Sons, Ltd.	5	5	0
The Premier Drum Co., Ltd.	105	0	0
The De-Havilland Aircraft Co., Ltd.	100	0	0
The British Aeroplane Co.	50	0	0
Standard Telephones & Cables, Ltd.	100	0	0
The Telephone Condenser Co., Ltd.	5	5	0
David Brown & Sons (Huddersfield) Ltd.	50	0	0
Leyland Motors, Ltd.	100	0	0
Hoover, Ltd.	100	0	0
W. Sisson & Co., Ltd.	5	5	0
George Blackburn & Sons, Ltd.	10	10	0
J. E. Baty & Co., Ltd.	21	0	0
The Horstmann Gear Co., Ltd....	25	0	0
Harbots, Ltd.	10	0	0
Williams & Williams	250	0	0
Crossley Motors Ltd.	25	0	0
A. V. Roe & Co., Ltd.	26	5	0
William Ayrton & Co., Ltd.	20	0	0
Rotol Ltd.	20	0	0
Gloster Aircraft Ltd.	5	5	0
Total	£1093	18	0

In addition to the above the Council gratefully acknowledge the gift of a case of instruments containing dial gauges and accessories from The Denfords Engineering Co., Ltd.

Past Journals of the Institution.

Owing to the fact that the library was completely destroyed by enemy action it has been necessary to request members to assist in completing a set of the Proceedings of Institution for future reference purposes. It would therefore be greatly appreciated if any member would be willing to spare his copy of any of the following Journals.

1938. November, December.
1939. January, March, May, November.

Change of Address.

To enable up to date records to be maintained it would be of great assistance if members would immediately notify the Institution of any change of their address. Such action will ensure members receiving their Journals, notices of meetings, etc. During recent weeks a large number of publications have been returned by the Post Office who have been unable to deliver on account of the forwarding address being unknown.

BOOK REVIEW.

Plastics for Production, by Paul I. Smith. Published by Messrs. Chapman & Hall. Price 12s. 6d.

This book can be considered as a most useful work of reference for all branches of the Plastics industry. It covers the whole field of the many Plastics now commercially used, and a valuable guide as to choice is given by outlining the various uses for which each class is most suitable. A description is also included of the characteristics of the main types of moulds in general use, and methods of fabrication.

There are many tables which present in a comprehensive manner, all the physical, electrical and mechanical properties and there is much information regarding plastics as a substitute for glass, including optical properties.

Abstruse mathematical and chemical data have been deliberately avoided for the purpose of simplicity, but not at the expense of clarity of explanation.

A bibliography of Modern books, and periodicals of English, American and foreign publication is given at the end of the book.

The mass of useful and concise information it contains should prove of great value to all users of plastics.

DEVELOPMENT IN ELECTRIC DRIVE OF MACHINE TOOLS

Paper presented to the Institution, Leicester Section, on 23rd March, 1944, by W. L. Sims, Esq., A.M.I.E.E., A.M.I.Mech.E.

Introduction.

Mr. President and Gentlemen: It would, I suppose generally be regarded as an understatement of fact to say that the demands made on the machine tool do not get less. The general trend is towards increased rate of metal removal, greater precision, and in some cases automatic sequence of operations.

To meet these demands, the maker often finds it convenient to supplement his mechanical devices by optics, hydraulics, electrics, and the like.

In my talk tonight I wish to describe how electrics have been used in connection with some of these modern problems.

We know that where we require high cutting speeds we can sometimes cut out the internal transmission and mount the cutting tool or workhead directly on the motor shaft, and we can also sub-divide the various cutting points, feeds, traverses, etc., and drive them independently. From a control point of view, the electric control, such as push buttons, came to be accepted as the more usual means of starting and stopping a machine once individual drive was established, but we can clearly see electrics reaching out beyond fulfilling the function of driving and performing the simple control operation of starting and stopping.

Reversing.

As an example, reversing is obviously a logical step further in the function of electrics applied to machine tools. An electric motor starts up just as readily in either direction, and in the case of a 3-phase motor it is only necessary to change over any two lines feeding the machine: obviously a very simple switching operation. A point to underline is that the reversing can take place very fast, and an interesting example of this is shown in Fig. 1, where we develop occasional reversing to a fundamental principle in the operation of a radial tapping machine. The tapping head is designed around the principle of high speed electric reversal. When the head is switched on it commences to feed downwards and at the end of the stroke strikes a tappet operated switch which reverses

the motor and the feed. A final tappet completes the cycle. Reversal of the ½ h.p. motor can take place up to 40 times per minute.

Speed Control, Changepole Motors.

One of the fundamental problems associated with machine tool design is often that of speed control, and it is interesting

Fig. 1.

to examine the electrical possibilities of speed control, together with other functions which are sometimes required with or are associated with speed change. Where a single speed only is re-

quired, the squirrel cage induction motor is undoubtedly the obvious choice of drive, due to its simplicity and general robustness. Its speed, however, is a function of the number of poles and the frequency and is expressed by :—

$$\text{revolutions/second} = \frac{\text{frequency}}{\text{No. of pairs of poles}}$$

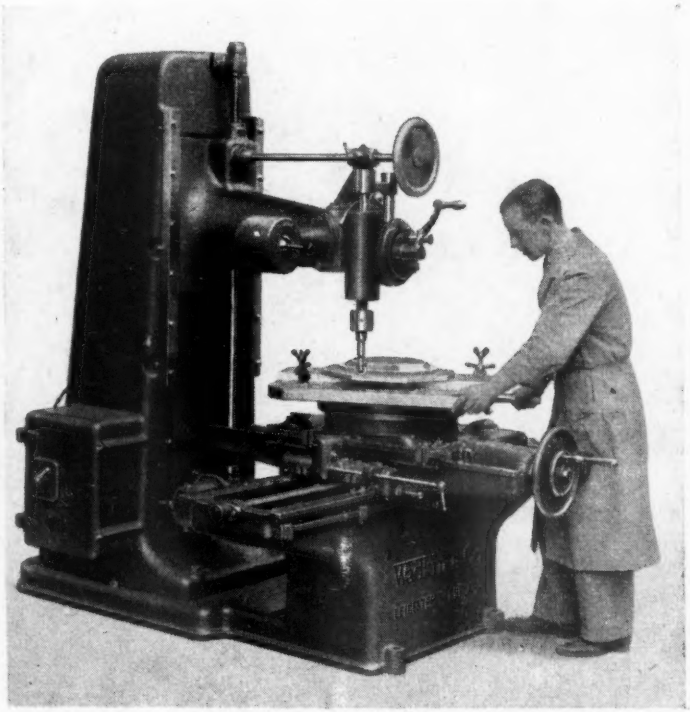


Fig. 2.

From this expression it is obvious that the squirrel cage motor cannot be regarded as a possible means of obtaining speed variation, unless some means can be found of conveniently varying the frequency. Unfortunately, no such means is at present available, so that speed variation is only possible in steps by pole changing. As is well known, it is possible to wind a squirrel cage motor so that

its winding can be reconnected in the ratio of 2/1, and it is also possible to have more than one winding on the motor, so that where the permissible speeds correspond with the speed steps required by the machine, we have convenient and non-deteriorating speed control which can of course very simply be obtained in either direction. The range is sometimes extended and multiplied by being used in conjunction with a simple two step gear box. It is perhaps not so well known that this type of motor can be wound for more than 4 speeds. Fig. 2 shows a pattern milling machine which is sometimes required with 5 speeds. In such cases the drive is from the motor with three windings arranged to run at synchronous speeds of 1,500, 1,000, 750, 500 and 375 r.p.m. giving spindle speeds of about $2\frac{1}{2}$ times. This particular combination of three windings is capable of giving two speeds per winding, if six speeds are required.

Stepless Speed Variation. A.C. Motors.

What answer can electrics offer to the stepless speed change problem ? In passing we should mention that the slip ring induction motor can give stepless speed variation by reducing the rotor voltage which is possible in a simple manner by variable resistance in the rotor. Resistance control, however, in the main current carrying circuit of apparatus is not recommended because it introduces losses which vary in proportion to the square of the current times the resistance, and further more, unless the load is held constant the speed will vary with the load on a given setting. Generally speaking, therefore, slip ring control is not a suitable means of speed variation for machine tools, particularly for driving cutting spindles.

The A.C. commutator motor is designed to overcome the inherent difficulties of speed control associated with a slip ring induction motor, and its operation is based on the principles of injecting a regulating voltage taken from either an internal regulating winding or an external regulator. The former machine has its speed varied by altering the position of the brushes, and the latter machine has its speed varied by movement of an external regulator, Either constant torque or constant horse power characteristics can be obtained.

It must be admitted that there is no A.C. alternative to compare with the D.C. motor, which can directly give, when required, infinitely variable speed control combined with other control features, such as accelerating to a pre-set speed, allowing top and bottom speeds to be picked up as required for say fine feed or fast approach, accompanied by dynamic braking and reverse.

Stepless Speed Variation, D.C. Motors.

Fig. 3 shows diagrammatically the D.C. motor. The main current passes through the armature circuit and a very small current passes through the branch circuit which supplies the field coils. Speed increase of 3 to 1 is possible by varying this small current

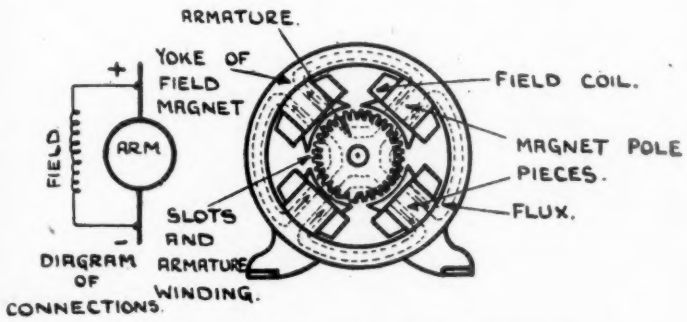


Fig. 3.—Diagram of D.C. Motor together with Connections.

by means of a variable resistance (i.e., shunt regulation). The horse power does not rise with the speed. Speed decrease can be obtained by inserting a resistance in the armature circuit, but this has the same objections referred to in connection with the slip ring motor.

Stepless Speed Variation, Ward-Leonard Control.

When a large speed range is required, say in the order of 10/1, the well-known Ward-Leonard control, used for planer drives and grinder workhead drives, offers a very satisfactory solution. It consists of a motor generator set, the generator armature is connected solidly to the armature of the motor driving the machine (see Fig. 4) without any control gear, and the voltage of the generator is varied by shunt control in exactly the same way that the D.C. motor had its speed varied. This, of course, varies the voltage across the motor and consequently the motor speed.

The arrangement has constant torque characteristics, but if shunt control of the motor is also used it will have constant horse power over this part of the range. Speed control is again obtained by the manipulation of very small amounts of power. It should be noted that reversal is also readily obtained by the simple expedient of reversing the generator field. Here again note the main armature currents are not interrupted.

The objection to Ward-Leonard control for machine tools, is that it requires a separate piece of rotating machinery not associated with driving the machinery, and also power is necessarily obtained from a small reservoir of power instead of having the mains behind it. The obvious need is to be able to connect a D.C. motor to

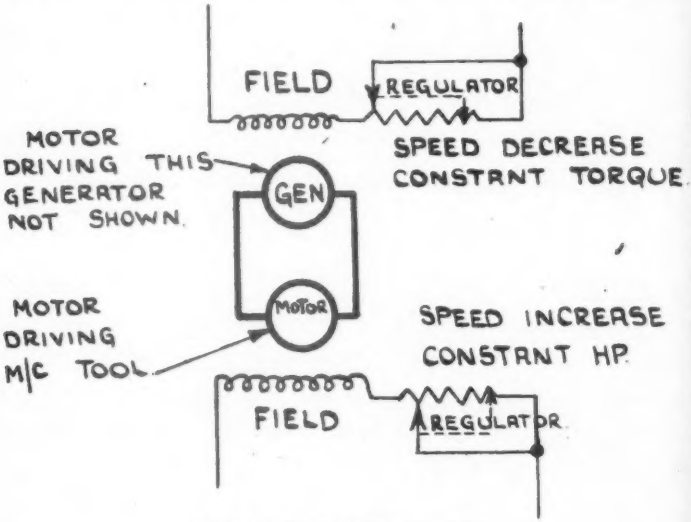


Fig. 4.—Diagram Ward Leonard set.

A.C. mains by as direct connection as possible without going through the performance of converting A.C. to mechanical energy and re-converting to electrical energy of another type, i.e., D.C. for further conversion to mechanical energy by the unit driving the tool. The answer to this problem is rectification, and in order to give an accurate picture of what is involved I should like to consider certain fundamentals.

Rectifying Valves.

It has now been established that all atoms are made up of the same building bricks, and the only differentce between one element and another is that it has a different number of building bricks in its atomic structure. The building bricks consist of positive charges of electricity which we know as protons, and negative charges of electricity which we know as electrons. When a material is heated it tends to throw off electrons. If a posi-

tively charged plate is placed above the heated body, since unlike charges attract, emitted electrons are drawn towards the positive plate. In practice, the positive plate or anode and the heated body or cathode filament, are housed in an evacuated tube or bulb. It will be noted that when the direction of voltage is reversed, the anode becomes negative and rejects the electrons, therefore no current can flow and hence the name of "Valve." The current in such a valve is limited to a few milliamps because it has a high resistance. If, however, an inert gas is used instead of a vacuum, an arc can be formed between anode and cathode which forms a low resistance path, so that only a very small part of the voltage applied is needed to drive the current through the valve, therefore the anodes or A.C. terminals are only at a slightly higher

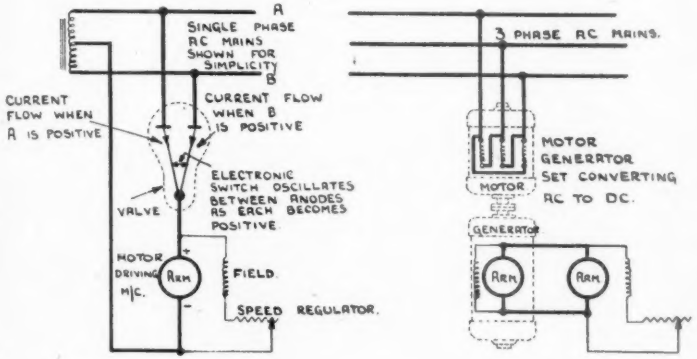


Fig. 5.—Comparison of valve rectifier and motor generator set.

potential than the cathode or positive D.C. terminal. The remainder of the voltage is therefore available for doing useful work on the D.C. side of the valve.

Speed Control from Rectified Current.

A valve with one anode if connected to an A.C. supply would obviously only suppress the negative half cycle. If we connect a single phase A.C. supply to two anodes as shown on the left of Fig. 5, the valve acts as a rapidly moving switch picking off each half cycle as each anode becomes positive due to current reversal and supplying a uni-directional pulsating current to the cathode or positive D.C. terminal, which, when suitably smoothed by means of a choke coil, i.e., the electrical equivalent of a flywheel, allows a D.C. motor to take current direct from A.C. mains, and speed varia-

tion can thereby be obtained by means of shunt regulation, that is, in the order of 3/1. The alternative of using a motor genera-

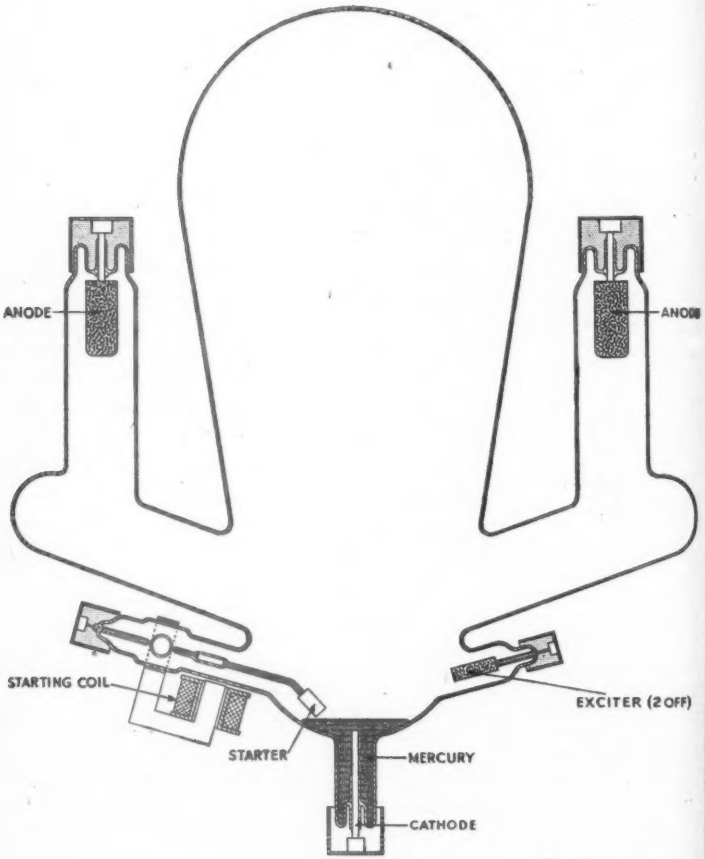


Fig. 6.

tor set is shown on the right of Fig. 5. In connection with our power valve, the one with the inert gas, we know this as a " hot

cathode." Since the filament is destructible it is not altogether satisfactory for industrial operation and another type of valve is used with a mercury cathode, which is fired by means of a starting

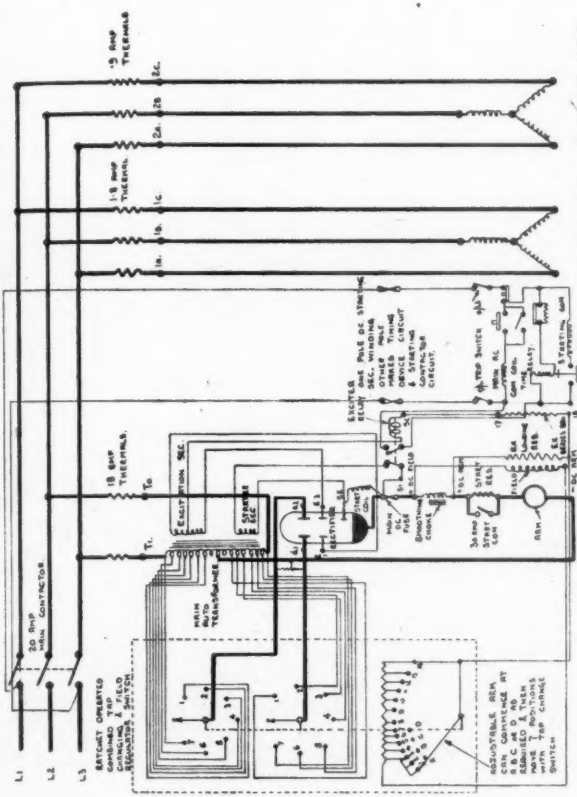


Fig. 7.

anode being drawn towards the mercury by an external electromagnet, which is short circuited when the anode dips in the mercury (see Fig. 6). Thus the starting anode is released, and when it leaves the mercury it causes a spark which initiates an arc to the excitation

anodes. The stream of mercury vapour ions, visible manifestation of which is the arc, bombard the mercury at the cathode end of the arc discharge and maintain a hot spot on the mercury. The hot

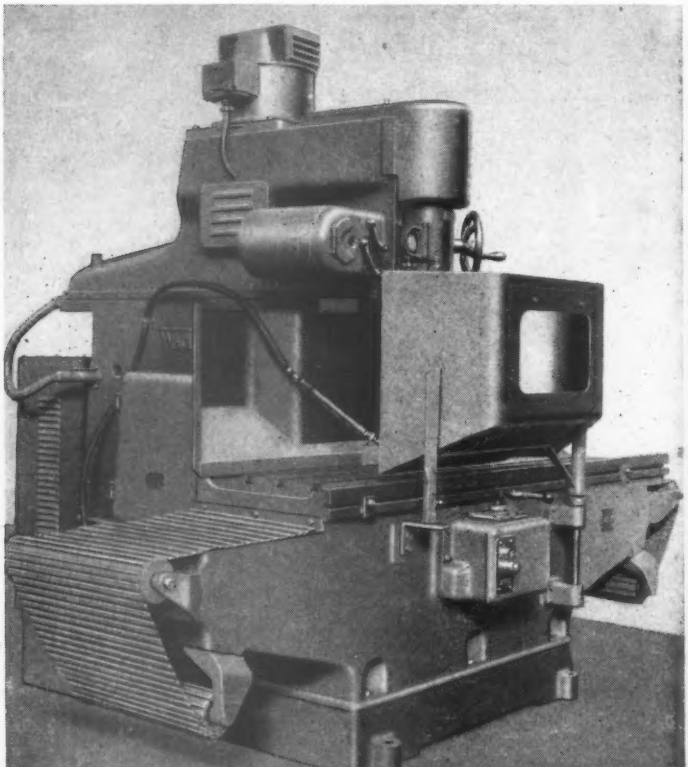


Fig. 8.

spot replaces the filament cathode in the previous type of valve and thus forms an indestructible cathode. It can be explained that the excitation anodes are provided in order to keep the valve firing irrespective of whether the main load is connected to the main

anodes or not. They serve a very useful purpose for a D.C. motor application by supplying a constant voltage for the motor field. In the case of 3-phase supplies there are three main anodes and the electronic switch connects each anode in turn to the cathode as it becomes more positive with respect to the other two anodes. If a wider range of speeds is required than that which can be obtained by shunt regulation, a transformer, which in this application acts as an electrical gear box, can be arranged to have various taps which will feed the main anodes at various voltages, thus producing speed change by voltage control as well as shunt control.

Fig. 7, shows a diagram of connections for a vertical milling machine for face milling large non-ferrous components which has 28 different spindle speeds from 300 to 2000 r.p.m. Fig. 8 illustrates the machine. The ratchet switch on the top left hand side of the machine simultaneously selects transformer tappings and inserts shunt resistance as required. The vertical motor at the top of Fig. 8, drives the spindle by belt and is essentially a constant torque machine, but tends to have a higher torque at the lower speeds by virtue of field forcing, i.e., higher field currents at the low voltage taps.

In a further development of this method of control we are called upon to give stepless speed variation over at least a speed range of 60/1 with reciprocating features, automatic selection of preset feed, fast approach, slow approach, and also quick return, together with braking. To do this we depart from normal mechanical switching as employed in the ratchet switch and employ our electronic switch which we have already seen operates with precision at speeds beyond our normal conception.

Fig. 9C, shows an alternating current voltage which could be connected to the anode of a rectifier. If between the anode and the cathode there is another electrode which we call a control grid, and this has impressed upon it the smaller wave of voltage shown, it will be clear that current cannot flow unless the control grid is positive, irrespective of the potential of the main anode. In Fig. 9C the two waves of voltage are superimposed upon one another so that the zeros and maximum values correspond. Consequently, both the control grid and the main anode become positive at the same moment; consequently, current flows between the anode and cathode during the whole time the anode is positive. In Fig. 9B, however, the grid wave of voltage has been moved towards the right, and the grid does not become positive until the main anode voltage has reached its maximum value, and therefore current can only flow for half the time the anode is positive. In Fig. 9A, the wave of grid voltage has moved further still towards the right and does not become positive until the moment the main

anode voltage becomes negative. Consequently, no current flows at all. It will, therefore, be appreciated that if a wave of voltage can be applied to the control grid and moved across the main anode voltage as shown, the grid can conveniently trigger the current at any selected point on the wave and the *average value*

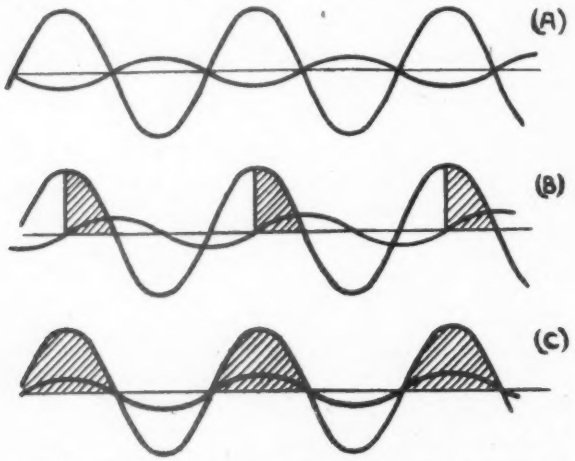


Fig. 9.—Single-phase grid-controlled rectifier (resistance load).
Shaded areas indicate current conduction.
(A) Grid voltage 180° out of phase.
(B) Grid voltage approximately 90° out of phase.
(C) Grid voltage in phase.

of the voltage can be varied from zero to a maximum on the D.C. side, and as the speed of a D.C. motor varies as the voltage, here we have a means of stepless speed variation. It will be appreciated that the shaded chunks shown are smoothed out to only a unidirectional ripple.,

The apparatus required for grid control is about the size of a fractional horse power motor, and rotates through a portion of a revolution. When it is prevented from rotating at all it gives minimum speed. When allowed to rotate to its maximum movement it gives maximum speed, and when interrupted at any point between minimum and maximum by means of a stop which can be set by the operative by means of a convenient handle, it gives pre-selected speeds. This stop is automatically withdrawn for fast speeds.

A machine will now be described embodying these and other

features. The machine illustrated in Fig. 10, is designed for machining aluminium alloy extrusions used for spar booms for heavy bombers. The larger of these aluminium alloy extrusions are just

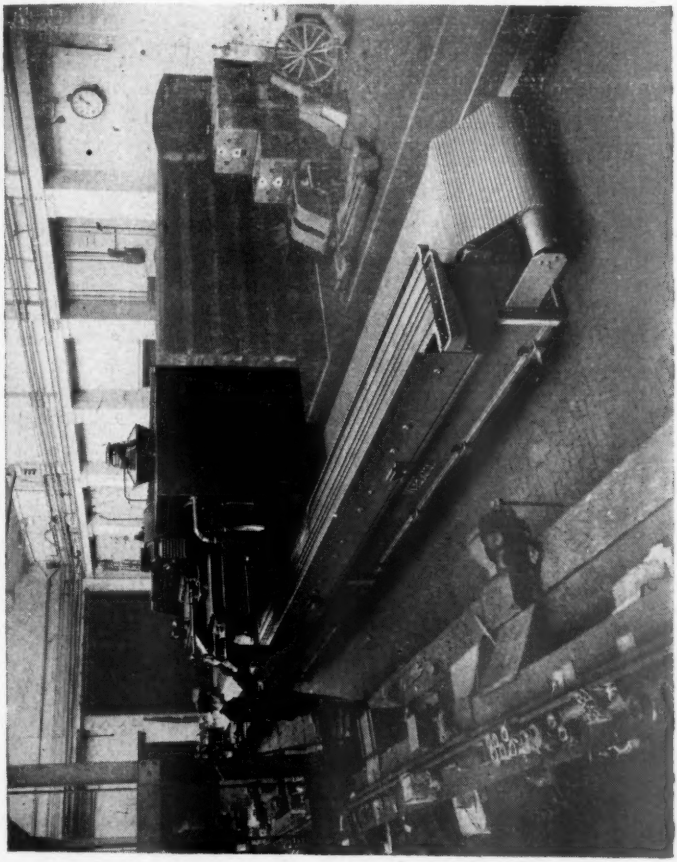
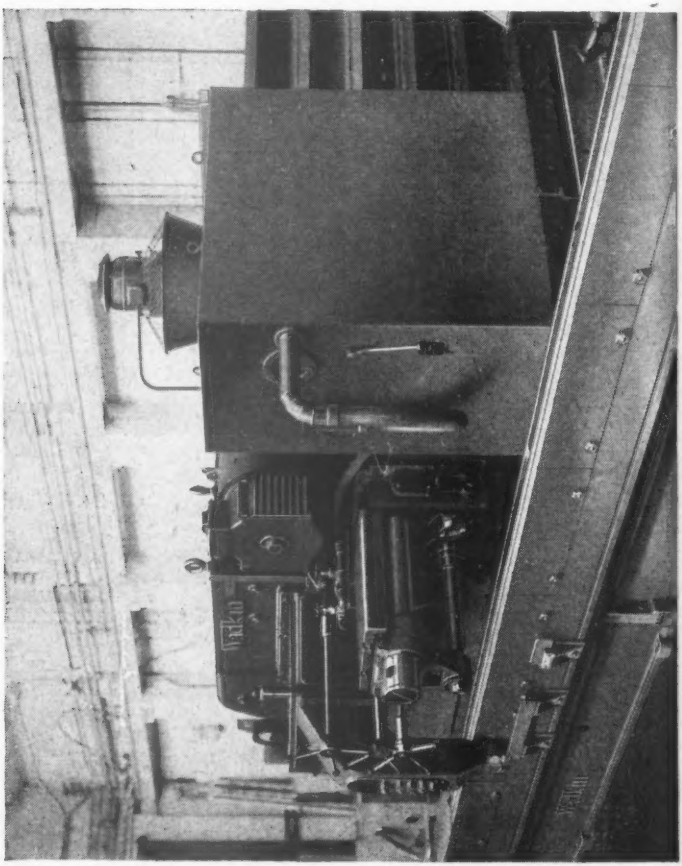


Fig. 10.

under 4 in. by 3 in. section, and approximately 30 ft. long. Some operations include a very fast rate of metal removal such as machining out the lightening gaps which are sometimes approximately 2½ in. wide by 2¼ in. deep, and are machined at the rate of 2 ft.

per minute or more, two at a time, using tungsten carbide tipped cutters. As can be seen from the illustration, the machine consists of a fixed table carried on an extension of the main bed casting,



and a travelling carriage, carrying the cutter spindle, moving along the bed. The main power movements consist of a spindle drive, a feed drive, and a spindle rise and fall drive. The spindle motor is illustrated in Fig. 11 and consists of a D.C. motor which

gives 30 to 40 h.p. when driving the main spindle at infinitely variable speeds from 200 to 500 r.p.m. and 75 to 100 h.p. when driving main spindle at 500 to 1000 r.p.m.

The lower speed range is used with high speed steel cutter equipment, and the high speed range with tungsten carbide cutter equipment.

In view of the large amount of power required to remove metal at the above rates, the mechanical transmission has been made

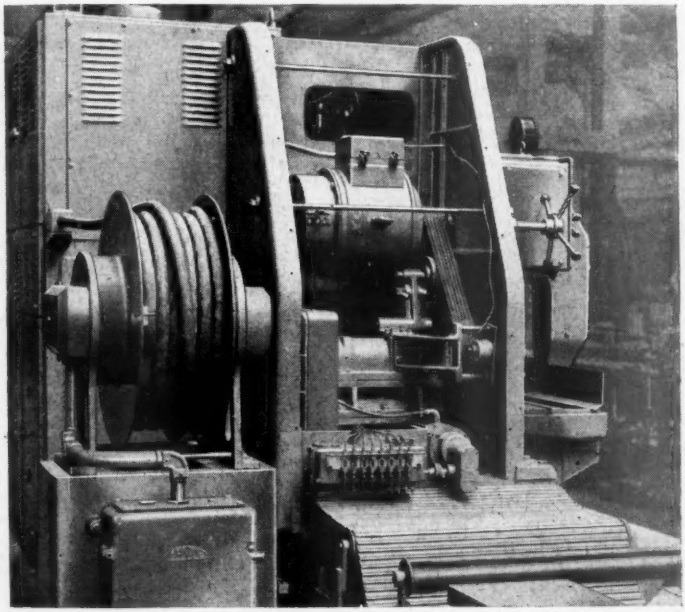


Fig. 12.

extremely simple, consisting of a vee drive from the motor to the input shaft which drives the main spindle through one set of reduction gears. The whole of the speed, range, starting and stopping the spindle, etc., is obtained electrically. The motor sits on the gear box on anti-vibration mountings and rises and falls with the cutter spindle.

The D.C. supply to the motor is obtained from a rectifying valve. The two speed ranges are obtained by means of two taps on a

transformer which for this application as in the previous example is similar to an electrical gear box. Infinitely variable speeds on both ranges is by shunt control described above.

The feed motor is shown in Fig. 12 and also consists of a 5 h.p. D.C. motor which drives the pinion meshing with a fixed rack on

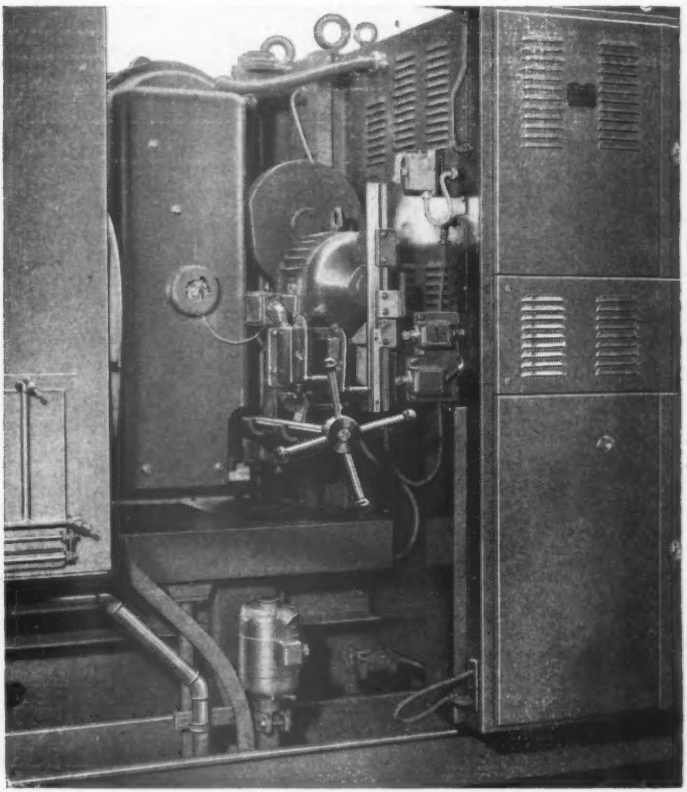


Fig. 13.

the bed via vee ropes, pick-off gears, and worm and wheel reduction.

The whole of the speed range is obtained electrically by means of a grid controlled rectifier, and feed speeds from 2 in. to 40 in. per minute are possible with return speed of 10 ft. per minute.

The pickoff gears referred to above double the speed range. On the illustration the following are also shown :-

(a) The main incoming A.C. switch, (b) the spring operated cable reel which pays out cable to the main cubicle as the carriage moves along the bed and winds it up by means of a spring on return, (c) the control and valve cubicle, (d) the oil pump motor feeding the bed and the rack pinion and (e) the tachometer generator.

Fig. 13 shows the rise and fall motor drive for the spindle. This is a changepole motor and raises or lowers the spindle at 7 in. per minute fast rise or fast lower, and 1 in. per minute for fine feed lower when sinking the cutters into the lightening gap or precision setting the cutter spindle to a given centre height.

The control limit switches can be clearly seen on the illustration. The top switch limits the raise movement. The middle switch the fast lower movement, and the bottom switch limits the slow lower movement. Also on the illustration can be seen the coolant pump motor which moves in a trough behind the machine, and the spindle tachometer generator which feeds the tachometer indicating the spindle speeds. To the right is the main cubicle. Behind the rectangular guard through which can be seen the tachometer generator is the vee drive from the main motor to the spindle gearbox.

Fig. 14 shows the control station which has a selector switch for selecting either push button or automatic operation, start and stop spindle buttons, fast raise, fast lower, and slow lower spindle, horizontal feed, fast horizontal feed, fast return, and stop feed and return buttons.

On the left of the illustration towards the top can be seen the spindle and feed tachometer indicators. To the left is the capstan handle used to adjust the speed of the feed motor. Hidden on the right of the panel is a similar handle used to adjust the speed of the spindle motor. On the top is an ammeter indicating the power taken by the spindle motor. A signal beacon is also on the top of the control box indicating when the main switch is closed. The illustration also shows the fast and slow switches marked F and S, which as depressed by dogs seen along the table of the machine, give fast and slow feed speeds irrespective of the pre-set speed by the grid control method described above.

The bronze bar seen towards the left is secured to the cutter spindle vertical saddle and rises and falls with the cutter spindle, as also does the switch mechanism seen at the bottom of this bar. This mechanism consists of two tappet switches, one leading the other. These tappet switches are contacted by the vertical stops which can be seen in the illustration.

The first stop operates the down switch by switching off the horizontal feed movement and introducing vertical down movement, which continues until the tappet is able to pass under the stop, when horizontal movement is resumed, thus sinking the cutters into the spar for milling out the lightening gap.

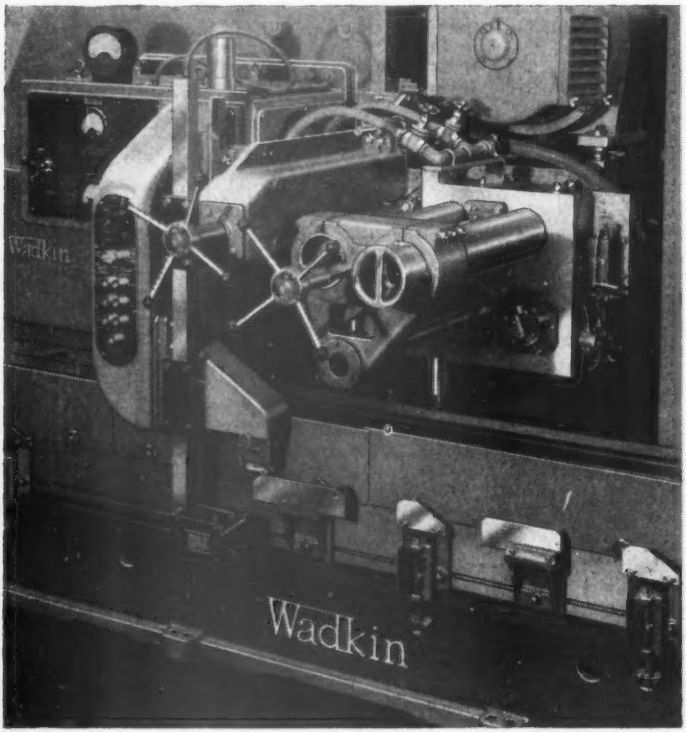


Fig. 14.

At the end of the gap, the " Up " stop is met and the cutters rise out of the gap until the tappet is free to pass over the top of the stop, when horizontal movement is resumed. This is probably at fast approach to the next gap, and the operation is repeated until at the completion of the final gap, the cutter head is raised to the top position when the raise limit switch on the back of the machine,

already noted in Fig. 13 is contacted, when this movement stops and the carriage returns at top speed to the start position and stops,

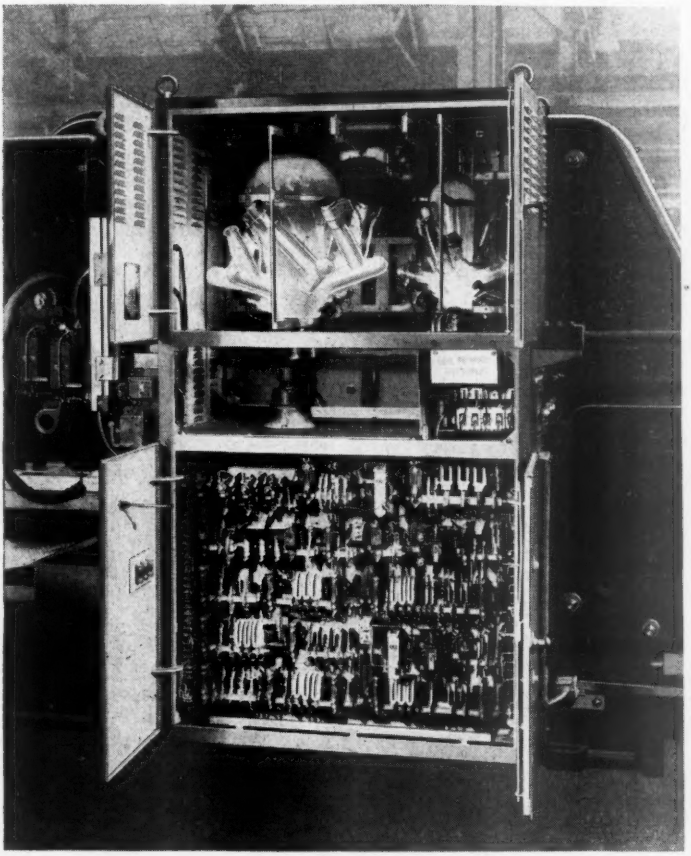


Fig. 15.

thus completing the cycle. All the feed and slow lower movements are electrically braked.

Fig. 15 shows the cubicle which is 80 in. high by 46 in. wide by 34 in. deep. This houses the main spindle valve and the feed

motor valve, the latter being grid controlled, and all the automatic control gear to carry out the automatic and push button operations described above. The transformers are housed behind the contactor gear.

The size of this equipment should be mentally compared with a Ward-Leonard set to drive a 75/100 h.p. planer drive, plus a 5 h.p. drive, plus all the control gear. It will be noted that the only rotating apparatus, other than a cooling fan, is the driving motors. Thus all this electrical apparatus could be mounted on the moving carriage, it only being necessary to bring the main A.C. supply leads to the cubicle.

SOME APPLICATIONS OF ELECTRIC POWER TO MACHINE TOOLS

Paper presented to the Institution, Coventry Graduate Section, on 6th March, 1944, by C. Hayward, Esq., Grad.I.P.E., A.M.I.Mech.E.

THE application of electric power to machine tools consists primarily of supplying the motive power by means of an electric motor or motors, and also of carrying out auxiliary functions such as control of automatic duty cycles, operation of quick traverse motions, provision of safety devices, etc.

The primary requirement, that of supplying motive power, may be accomplished, either by the provision of a number of large electric motors, each driving a gang of machines by means of lineshafting, or by fitting each machine with a comparatively small motor, which may be attached to the machine to form a self-contained unit.

I propose to deal first with the requirements of the group drive, since this method is probably the oldest, and is, from the electrical point of view undoubtedly the simplest, requiring merely a motor and starter of suitable capacity. Under these conditions the most obvious consideration is the horse-power rating of the motor, and this need not be equal to the total maximum output of the machines in the group, since they will not all be employed on maximum power output at the same time. A diversity factor, which may, in some cases, be as low as 65% will therefore exist for each particular group of machines and when this has been determined, either by experiment, or, more often, from past experience of machines on similar work, the H.P. rating of the motor can be decided. The motor may run at any speed which is not too high for the mechanical transmission, correct speeds for each machine being obtained by means of the lineshaft pulleys. Standard A.C. motor speeds on 50 cycle supplies are approximately $6{,}000 \times \frac{1}{N}$ where N is the number of poles in the stator winding. This gives speeds of approximately 3,000, 1,500, 1,000, 750, 600 r.p.m., etc., and most British manufacturers standardise the speeds of their D.C. machines at similar figures to facilitate interchangeability.

While the actual speed of the motor is not vital, it *is* important that the speed shall not fluctuate violently when the load on the motor is varied and one must therefore choose a motor which maintains a reasonably constant speed under all load conditions. From the foregoing it will be apparent that, in order to choose the best

motor for the purpose, one must examine the behaviour of various types under varying conditions of load.

Considering first *Machines for use on D.C. Supplies*, these may be either Series, Shunt or Compound Wound, but in all cases these formulae apply :—

$$\text{Torque } T = \phi \, I_A \frac{Z\,P}{20MA} \qquad \text{Speed } N = \frac{E}{\phi}\left(\frac{60A}{PZ} \times 10^8\right)$$

ϕ = Flux density of the magnetic field (ppl. to If).

I_A = Armature Current (varies with load).

E = Voltage applied to armature (in this case supply volts).

All other quantities are constants depending on the design of the particular motor under consideration.

In Series Wound Motors, the field winding is connected in series with the armature, and carries the full armature current. Therefore at starting and low speed running ϕ is ppl. to I_A^2 and T ppl.to I_A^2 when saturation of the magnetic circuit has taken place ϕ is ppl. to I_A and T ppl. to I_A^2. This gives an extremely high torque at starting and at low speeds.

Field strength (ϕ), however, will be very small on light loads due to the low value of Ia and therefore, since, from the speed equation N is ppl. to $1/\phi$ it follows that speed will fluctuate violently under varying load conditions and may become dangerously high when running light. This type will therefore be unsuitable for the majority of machine tool applications.

The field circuit of the Shunt-Wound Motor, is connected in parallel with the armature, and its exciting current is therefore independent of the load current. Since field strength (ϕ) is now constant for all conditions of loading, the machine will theoretically maintain constant speed throughout its working range, but in actual practice armature reaction will cause the speed to fall slightly as load increases. For ordinary purposes, the shunt wound machine may be considered a constant speed motor, and as such is widely used for machine tool drives.

Compound Wound Motors have two field windings, one of which is connected in series with the armature, and the other in parallel, and the motor will have either series or shunt characteristics, depending on which winding predominates. For the purposes of this paper the term " Shunt Wound Motor " will be taken to include those compound wound machines which have shunt characteristics.

Direct Current Starters.

Very small D.C. motors may be switched direct-on-the-line without damage, but if this is done with larger machines two main features must be considered :—

The motor must have full field strength at starting, to give good

acceleration under load, and to prevent dangerous overspeeding if lightly loaded. Also, at the instant of switching-on, there will be no back—e.m.f., which means that the armature current is limited only by the very low resistance of the armature circuit, and a considerable current surge will be caused.

To guard against these dangers the controller is arranged, so that the field connections are made in advance of those to the armature, and, in addition, a resistance is coupled in series with the armature circuit, in order to limit the current flowing to a reasonable value. This resistance is cut out in steps (usually in Geometric Progression) until the full armature current is flowing. This operation may be done either manually or automatically, but for group drive applications where starting and stopping is likely to be infrequent, a manual starter is usually suitable.

Machines for Use on Alternating Current Supplies.

Owing to the limited time at our disposal, I have restricted my survey of A.C. motors, to those suitable for use on polyphase systems, since these cover the vast majority of everyday requirements. All these machines have stators or field windings, constructed so that the application of an alternating current, will set up a rotating field, and the approximate speeds of 50 cycle motors mentioned earlier in the paper, are the actual speeds at which this field rotates. These are known as the synchronous speeds of the particular machines to which they apply.

Induction Motors as their name implies, derive their power from the current induced in the rotor conductors when they pass through the rotating magnetic field, and this means that the rotor speed must differ from that of the rotating field, by an amount sufficient to induce the required current. This difference of speed is called the "slip" and is usually expressed as a fraction of synchronous speed. The torque developed by an induction motor may be obtained from the expression :—

$$T = \delta EK \times \frac{R_2}{R_2^2 + \delta^2 X_2^2} \times C$$

δ = Slip expressed as a fraction of synchronous speed.

E = Voltage applied to the stator.

R_2 and X_2 = Rotor resistance and reactance.

K and C are constants for the particular motor.

Under running conditions, torque will be a maximum when $R_2 = \delta X_2$ and this means that since R_2 and X_2 are constant for the particular winding, it will be necessary to introduce additional resistance into the rotor circuit, if maximum torque is required at starting, i.e., when $\delta = 1$.

The Wound Rotor induction motor has a rotor winding similar in many respects to a D.C. armature, but having its conductors brought out to slip rings, instead of to a commutator. These slip rings may be either short-circuited together, or coupled to an external circuit. By this means external resistance may be employed to give a good starting torque, and cut out in steps as the machine runs up to speed.

Squirrel Cage Rotor Induction Motors derive their name from the type of rotor used, in which the conductors take the form of metal strips, joined at either end to short-circuiting rings, rather like the bars and hoops of a squirrel cage.

This type of rotor is extremely robust, and very suitable for high-speed working ; but since it is permanently shorted within the motor, the rotor resistance cannot be varied.

Advantages of the S.C.R. machine are :—

Robust construction and ease of manufacture.

Starting and pull-out torque may be up to 2 or 3 times full load torque.

The motor gives good acceleration when starting.

These advantages are, to some extent, offset by the rather high current surge at starting, which may be 7 times full load current or even more in extreme cases, and the rather poor power factor of the motor, especially at starting $\left(\cos \phi = \frac{R_2}{\sqrt{R_2^2 + \delta_2^2 X_2^2}}\right)$.

Synchronous motors have the conventional rotating field, but the rotor has constant polarity, by virtue of a separate D.C. excitation, or, (in the case of very small machines) permanent magnets. The rotor runs at the same speed as the rotating field (hence the name Synch. Motor) and if pulled out of synchronism by a heavy overload, the machine will stop. The advantages of the synchronous motor are :—

It is a truly constant speed machine.

Its power factor can be varied either leading or lagging by over or under-exciting the armature, thus making it useful for P.F. correction.

Chief disadvantages are :—

Need for source of D.C. excitation either from separate mains or a small exciting generator.

Very limited overload capacity.

Since the motor can run under its own power only at synchronous speed, means must be provided to run the machine up to speed from standstill.

Rather high cost compared with induction motors.

In an effort to overcome the chief disadvantages of the synchronnous motor, a machine called the Synchronous Induction Motor has been developed. This differs from the Synchronous motor, in that the armature or rotor has two windings :—an induction winding, which operates in the same way as an ordinary induction motor (i.e. it is self-starting and runs up to normal induction motor speed), and a D.C. exciting winding, which is energised when the machine is running, and will then pull into synchronous speed. Since induction cannot take place at synchronous speed, the Induction Winding is inoperative during normal running, but, if heavy overloading causes the motor to pull out of synchronism, it will then run as an Induction motor until the overload is removed and synchronous running is resumed.

It will be readily seen from the foregoing that any of the types of motor mentioned will be suitable for group driving, but, since the machine will not be required to start under heavy loads, the cheapness and robust construction of the squirrel cage motor make it the best choice for the vast majority of cases.

Alternating Current Starters.

Induction motors may usually be switched direct across-the-line without damage to themselves, but the resulting current peak (which may be 7 times full-load current or more) may cause trouble in the supply system, and most supply authorities therefore insist that this practice shall be confined to comparatively small machines (usually up to about 7½ H.P.). Incidentally, those members who were concerned with the supply of machine tools to the U.S.S.R. during the period of the first Five Year Plan, may remember that comparatively large motors were supplied with direct-on starting, presumably to use for some of the large hydro-electric networks.

The starting current of wound-rotor induction motors, may be limited by the insertion of resistances in series with the rotor windings, and cutting out this resistance in steps, in similar manner to a D.C. resistance starter. This has the affect of causing the motor to start slowly, and also improves the starting torque of the machine.

Since the squirrel-cage motor has no external connections to the rotor, the above method cannot be used, but a method which can be applied to all types of induction motor, is to vary the voltage applied to the stator winding when starting.

For this purpose series resistance in the stator circuit may be employed, but this is somewhat wasteful and is therefore used only on small machines. Better methods are the star-delta starter, in which the motor is connected to the supply first in " Star " and then in " delta " or " mesh " and which has the effect of reducing the start ing voltage across the stator windings in the ratio of $\frac{1}{\sqrt{3}}$; and the

auto-transformer starter, in which the voltage reduction is made, by means of small auto-transformers, each having one or two tappings which permit the voltage to be increased by steps to the full working volts. By this means, voltage reductions down to about 40% of line voltage may be obtained. It must be borne in mind that in all cases torque is proportional to the square of the stator voltage, and it will follow that induction motors started by these methods will have comparatively poor starting torque.

In the case of two-phase motors, " star-delta " starting is replaced by the " series-parallel " method, in which the stator windng is constructed in two sections, which may be connected in series during starting, and then in parallel for normal running.

Besides providing for starting and stopping the motor, the control gear, whether A.C. or D.C., must also protect it against damage due to abuse, such as excessive overloading. This can be very simply done by the addition of fuses, which are satisfactory for many applications of small motors, operated at fairly constant speed. Under fluctuating loads, however, overload protection has its problems since, if fuses are set slightly above normal full load, peak loads, which may be of very short duration, will cause unnecessary stoppages, whilst if the fuses are made large enough to accommodate these peaks, a sustained high load may occur, great enough to damage the motor, but not sufficiently high to blow the fuse. It is usual therefore to use fuses of sufficiently high rating to avoid unnecessary stoppages and also to incorporate overload protection devices, operated either thermally or magnetically, which are constructed so that they may be operated either by high loads almost instantaneously, or by smaller loads maintained over a correspondingly longer period.

It will be noted that on all types of starters (except, of course, direct-on) there is a definite sequence of operations to be followed, in order to start the machine, and this means that, if, in the event of failure of the electrical supply, the starter is left in the " run " position, damage to the machine, or injury to the operator, or both, may be caused when the supply is re-established. It is usual therefore, to provide a " No-volt " or " Under-voltage " release mechanism which will cause the starter to return to the " off " position under these conditions, but there are a number of types of starter mechanisms in use, particularly the smaller ones, which do not incorporate " No-volt " features, and care must be taken before specifying one of these types, to see that the omission will not be detrimental to safe working of the machine.

" Individual " Motor Drives.

The establishment of the electric motor as the most widely used power unit in the factory, was followed by the realisation of the

advantages, in the form of greater flexibility of shop layout, better lighting facilities, localisation of costly shut-downs, etc., which could be obtained if each machine were driven by a separate motor, and whilst the individual drive has the disadvantage of higher initial cost, (generally speaking) its merits are such, that in many large concerns, it has completely replaced the older system.

The fact that each machine is driven by a separate motor, enables us to determine exactly the type of duty which each motor will be required to perform, and time spent in examining all the conditions of service will be well repaid throughout the life of the motor. The actual torque which the motor will be required to exert, may be obtained on test by means of any of a number of types of torque meters or similar devices, either mechanical or electrical, but where a number of machines are to be tested, it is worth while to make up a test set comprising a motor of generous proportions for which data is available regarding efficiency, etc., throughout its working range, together with a recording wattmeter, which gives a permanent record of loading in graphical form, showing not only the values of high load points, but for how long they are maintained, and at what intervals they recur. In short, the recording wattmeter, will produce a complete load study of the operation under consideration, which may be filed, together with particulars of the machine and job, for reference at any future time.

Machine tool makers are frequently accused of fitting motors of unduly large horse-power to their products, but, it must be realised that in determining the power of motors for general purpose machinery, the ideal will be the one which exactly matches the maximum power which can be transmitted by the machine-tool, and this will be most satisfactory for the average user, who wishes to produce a wide variety of work on his machine. In the case of special-purpose machinery, or machines on which the variety of work can be limited, considerable reductions in power may be made as a result of careful study of the particular requirements.

In the case of individual drive, the motor will be mounted on, or in close proximity to, the machine tool, and more care must therefore be paid to drip-proofing and types of enclosure, even to the extent of total enclosure in extreme conditions. The transmission from motor to machine tool may be made by direct coupling, gearing, chain drive, or belting. The efficiency of the chain drive is proved by its many staunch adherents, but lower initial costs, coupled with ease of assembly, due to the absence of lubrication problems, etc., have led to an increasing tendency to employ more short belt drives, both by vee ropes, and endless flat belting.

Since the driving motor of an individual machine will be required to start and stop more frequently than that of a group of machines, due to setting up, etc., particularly on short runs, the use of auto-

matic control gear will be justified, and this may be located in any convenient position, and operated by remote push-buttons situated at the point most convenient for the operator. In this case, operation of the push-button completes the "starting" circuit, which is maintained by an auxiliary relay within the control panel. The change-over from "starting" to "running" conditions is made automatically at the correct instant, which may be determined on a fixed time basis (e.g. after a number of seconds) by means of a time-delay relay, or on large panels by a small motor; or, it may depend on the attainment of certain conditions within the motor itself, as in the case of the Back—E.M.F.—Starter of D.C. machines, which is controlled by the difference in potential between normal line voltage, and the E.M.F., which is generated within the motor itself due to its rotation, and which opposes the driving E.M.F.

The All-Electric Machine Tool.

In attempting to differentiate between the individually motor driven machine tool and the "All-electric" type, we find, not an obvious line of demarcation such as exists between the "group" and "individual" methods, but a phase of rapid evolution which has produced an infinity of slightly varying types, so intermingled that it is of little value to attempt to make a definite chronological survey. The term "All-electric" is, in itself, a dangerous expression to use at this time, since we are, as yet, merely upon the threshold of development, and I would therefore, define the "All-electric" machine as we know it today, as one in which the main control operations are carried out electrically, without the aid of purely mechanical devices, such as mechanically operated clutches, speed-changing and reversing gears, etc.

This definition, however, would restrict our survey to a very elite field, and I shall therefore include in my remarks, some machines in which, although they are not strictly in accordance with the definition, the mechanical controls are auxiliaries, and subordinates to the main electric scheme.

Considering first the selection of equipment for use on these machines, we find that the determination of our requirements must be still more detailed and exact, since all starting, stopping and reversing of the machine will be done by means of the motor. This means that the motor will always be required to start and stop under a certain amount of load, which may in some cases be considerable, due to the K.E., of the moving parts of both motor and machine tool. In many cases this load may be shown by the recording wattmeter, but in the case of machines having a high rate of reversals per minute, it is necessary to calculate the value of K.E., which is to be overcome. The magnitude of this K.E., also means

that provision must be made for braking, if loss of time is to be avoided when stopping the machines.

Small machines may be braked by "plugging," or switching straight over to the reverse connection, a series resistance being inserted in the case of D.C. machines, but this will naturally cause a surge of current and for larger machines other means must be adopted.

For rapid breaking of D.C. machines, dynamic braking is widely practised, by disconnecting the supply from the armature, the terminals of which are then short-circuited through a resistance, which, dissipates the energy generated by rotation of the armature. A similar method may be applied to Induction Motors, and is known as D.C. plug breaking. It consists of energising the stator winding with D.C., thus creating a constant field in which the short-circuited rotor rotates. In wound-rotor machines a series resistance may be necessary to limit the rotor current. Another common method, is the solenoid brake, which is a mechanical brake, usually of a friction type, operated electrically by means of a solenoid.

The A.C. squirrel-cage motor covers a wide field of requirements on light and medium machine tools, due in part, to its robust and inexpensive construction, and to the ease with which the stator and rotor units can be assembled as part of the machine tool. As we have seen, the motor runs at a constant speed, determined by the number of poles in the stator winding, and this speed can only be varied by altering the number of stator poles. This can be achieved by tapping the stator winding, so that, by altering the order of connections, the number of effective poles may be reduced by half, which has, of course the effect of doubling the speed of the motor. These are known as 2/4 pole, 4/8 pole, 6/12 pole windings, etc., and by incorporating two such windings in one stator a four-speed motor can be obtained. Common examples are 2/4/6/12 poles and 4/6/8/12 poles, and it will thus be seen that the theoretical ideal of geometric progression cannot be obtained by the use of the change-pole motor alone, but in many cases (e.g., capstan lathes), where speed changes are made frequently during operation, this disadvantage is outweighed by the ease with which the changes may be made, and for special cases, a combination of change-pole motor and mechanical gearing will give a fairly close approximation.

It has been shown that, whilst the squirrel-cage motor is not the best type for starting under heavy loads, its performance is, nevertheless fairly good in this respect (twice full-load torque is a common value for starting torque), and can be improved, at the expense of a slight reduction in full-load speed, by increasing the rotor resistance.

Another method of improving starting torque is to use a rotor having two sets of conductors, one of which has low resistance and

high reactance for normal running, whilst the other, a high resistance winding, gives good starting torque, but, due to its very low reactance, becomes inoperative as the motor speed approaches synchronism. By these means the squirrel-cage motor may be made to give very good acceleration under light and medium loads, either from standstill, or when pole-changing.

With well designed equipment, quite high rates of reversals per minute can be obtained without undue overheating, and with specially insulated motors, permitting high temperature rise, this performance can be still further improved.

With multi-speed change-pole motors, however, it should be borne in mind that for any particular machine the highest number of reversals per minute will of course be obtained at the slowest running speed, and, since the K.E., of the moving parts is proportional to the square of their speed of movement, the number of reversals obtainable at higher speeds, will be very approximately inversely proportional to the motor speeds. The change-pole motor gives approximately constant torque at all speeds (actually there is a slight reduction of torque at the lower speeds) and whilst it may appear at a first glance that increased power is necessary at low speeds, it should be remembered that the maximum torque which may be transmitted by shafts, spindles, gearing, etc., is constant at all speeds.

Another valuable feature of the squirrel-cage motor is the ease with which it can be braked by the " plugging " method, i.e., reversing the connections to the field windings, and maintaining the reverse connection until the motor comes to standstill. The reverse connection is broken when forward rotation ceases, either manually, or by the use of a relay fitted to the rotor shaft.

It must be remembered, however, that where the nature of the machine requires considerable inertial forces to be overcome when braking, the " plugging " method imposes a heavy load on the motor, and may cause serious overheating. This can be overcome by a friction brake coupled to the switch so that it is applied during the " plugging " period, and released during normal running. Switches can be obtained with provision for this arrangement.

We have seen that, with squirrel-cage motors, speed variation can only be made by a series of steps, which impose restrictions, both on the number of speeds available, and their actual values, which are governed by the frequency of supply. If wound rotor induction motors are used, speed reductions of about 10—20% can be obtained by means of variable resistance in series with the rotor circuit, maximum torque being approximately constant throughout the speed range. If they are designed for continuous duty and provided with suitable regulators, the starting resistances may be used for this purpose.

If stepless speed variation is required, it can be obtained by using an A.C. Commutator Motor, which has a stator winding arranged to create the usual rotating field, and a rotor, the conductors of which are brought out to a commutator, its brush-gear being short-circuited. The speed of rotation of the machine, is dependent upon the relative phase displacement of field and brush axes, and this displacement can be varied either by actually moving the brush-gear round the commutator, or by use of induction regulators. Speed variations of the order of 3/1 or 4/1 may thus be obtained with approximately constant maximum torque, load/speed characteristics being similar to those of a D.C. shunt-wound motor.

A more popular method of stepless speed variation, is the Ward-Leonard system, in which the A.C. motor drives a D.C. generator and a small exciter. The machine tool is driven by a D.C. motor which has its field circuit energised by the exciter at constant voltage, while the motor generator set, supplies the E.M.F., to its armature. Speed variations are obtained by varying the field strength of the generator, which is thus caused to supply a variable voltage to the D.C. motor armature, and as we have already seen, the speed of the motor will be proportional to its armature voltage.

By this means, speed reduction of about 7/1 may be obtained, and, since torque is proportional to load current, but independent of armature voltage, the maximum torque output will be constant throughout this range.

A still wider speed range may be obtained, if desired, by varying the voltage applied to the motor field, in which case, since torque output is porportional to field strength, the increase in speed will be accompanied by a reduction of torque, giving approximately constant H.P., over this part of the speed range. It will be noted that with Ward-Leonard systems, control is done through the generator and motor field circuits, with a resulting reduction in size of control gear. Reversing and braking features (obtained by reversing the supply to the generator field) are very good and special schemes may be incorporated to give improved acceleration and reversing, at the same time reducing the resultant peak curents.

Ward-Leonard equipments have the disadvantage of being somewhat bulky and expensive, but their advantages so far, outweigh their defects, particularly in the case of heavy machinery, that they occupy a wide and increasing field, notably in grinding and planing machines.

An interesting development of the Ward-Leonard System is the pilot-generator method of control. The pilot generator is a very small compound-wound machine having its shunt field winding in two sections which may be arranged either to assist or oppose each other. One of these sections is energised from the exciter and has therefore constant field strength, whilst the other section is

connected in series with the main generator armature, and its strength is therefore proportional to the load on the machine. By the inter-action of these two windings, any variation in the machine loading automatically vary the output of the pilot generator.

By using this pilot generator to supply field excitation for either generator or main motor, it is possible to obtain automatically a number of desirable features such as constant torque, speed, or horsepower within close limits ; uniform acceleration, variation of motor speed with diameter of work, etc., the regulation in all cases being governed entirely by working conditions, without the necessity of switching.

Electronic Control.

Very satisfactory results have been achieved in the field of electronic speed control, the general effect being similar to that of the Ward-Leonard equipment. In this case, however, the motor-generator set is dispensed with, variable voltage D.C. supply being obtained from the A.C. mains by means of thyratron rectifiers. The output voltage of the thyratrons is varied by means of a small rheostat in the grid excitation circuit, and maintained at the required value within 1 or 2% irrespective of load variations by a simple arrangement of resistances, condensers, etc.

The advantages claimed for electronic control over the W.L. system are :—

Wider speed range (up to 20/1) with higher efficiency, and better stability particularly at very low speeds.

Wiring circuits are simplified so that the system lends itself more readily to remote control, and replacement of rotating machinery by electro-static devices reduces mechanical wear.

For Direct-Current supplies, the shunt-wound motor, which is the most used type, has, as we have seen, a reasonably constant load-speed characteristic, with the added advantage that its speed can be easily varied either by reducing the voltage applied to the field circuit, or by varying the armature voltage. Field control will give speed increases of 100/150% or, if special field-forcing methods are used, about 500% with a corresponding reduction in maximum torque (i.e., constant horsepower). If armature control is used the effect will be to reduce speed, down to about 50% torque remaining constant. For small machines, both the above methods are employed, by simply inserting suitable resistances in series with either field or armature, but it will be apparent that resistances in the armature circuit will result in considerable wastage of energy, and on large machines, it is preferable to obtain a variable voltage to the

armature by means of a motor-generator set, used either on the Ward-Leonard principle, or, more usually, as a booster.

In the latter case, the motor-generator set is used in conjunction with the normal supply voltage which it will either augment (Boosting), or oppose (Bucking), depending on the polarity and magnitude of the generator field. This gives a speed range of 10 or 15/1, and has an advantage over the Ward-Leonard principle in that, at the extremities of the speed range, the generator is working with its full field strength and conseqently giving its maximum power output, whilst in Ward-Leonard equipment, it would be working on reduced field. Also, since a large part of the load is carried by the supply system, the motor-generator set may be correspondingly smaller, usually about half the power of the main motor.

Mounting of Motors and Controllers.

The modern tendency with electrically controlled machines, is to mount the motor and control gear within the body of the machine wherever possible, since this arrangement is extremely neat, offers the best protection from splashes and swarf, simplifies inter-connecting wiring, and facilitates the interlocking of covers, change-gears, etc., with the control gear to prevent accidents.

In order to assist in these layouts a number of special motor frames have been developed, notably those which are mounted by means of a flange instead of the orthodox feet, so that the motor may be fitted in the most convenient position. Where squirrel-cage motors are used, these may be obtained in the form of Stator and Rotor units without any casing or rotor shaft, so that when assembled within the machine body, they form an integral part of the machine tool. The simple and robust construction of these units, permits assembly by any good machine tool fitter, without fear of damage, and the resulting assembly can be made extremely sound mechanically, besides being pleasing to the eye. Care must be taken, however, to make adequate provision for cooling, and possible effects of temperature rise on the alignments of the machine tool, must be considered in detail.

Control gear of any type, from the simplest switch to complete control panels, may be obtained, by collaboration with the manufacturers, either enclosed in a robust metal container, of any convenient shape and size for mounting in the space available on the machine, or alternatively, mounted on a substantial panel for building into any available cavity. In addition to these arrangements, large controllers are often supplied, suitable for standing on the floor adjacent to the machine, and some very attractive cabinets, incorporating work stands, tool cabinets, etc., have been designed for gear of this type.

Where contactor gear is used, this may be controlled by push-buttons, limit switches, relays, etc., located in any convenient position. For manual control, either push-button or lever-operated switches may be used, both types giving that ease of operation generally called "finger-tip" control, and many users prefer the lever-operated switch to the push-button, since the lever may be easily located by touch, thus permitting the operator to keep his eye on the workpiece.

Auxiliary Electrical Functions.

In addition to supplying the motive power, a vast and increasing number of auxiliary duties are now performed electrically, advantage being taken in particular of the ease with which electrical controls can be duplicated, so that operation is possible from widely separated positions on large machines. Interlocking with mechanical control devices, is usually accomplished easily, the result being a very pleasing layout, both as regards appearance and ease of operation.

Electrically operated quick-traverse mechanisms have become almost universal on large machines, and are widely used on machine tools of the lighter types, to provide such refinements as intermittent cutting, and automatic duty cycles, whilst planers and similar machines, frequently employ solenoids, etc., to relieve the tools and prevent damage during the return stroke.

Work-holding provides scope for a number of applications, magnetic, electro-hydraulic, and electro-mechanical, whilst work-sizing and gauging is another fruitful field in which photo-electric or other types of relays can be arranged to interrupt the feed cycle of the machine when the workpiece has been reduced to the desired dimension.

One of the most valuable features of electric control is the ease with which safety measures can be incorporated, often in the form of quick-stopping, by automatic relays, or by conveniently located push-button stations. Here again it is most important to consider the effect of Kinetic energy in the machine, in order to prevent dangerous over-running after the switch has operated.

I think these features will be best studied in conjunction with a few illustrations of modern electrically operated machine tools.

Research Department: Production Engineering Abstracts

(Prepared by the Research Department.)

NOTE.—*The Addresses of the publications referred to in these Abstracts may be obtained on application to the Research Department, Loughborough College, Loughborough. Readers applying for information regarding any abstract should give full particulars printed at the head of that abstract including the name and date of the periodical.*

HEAT TREATMENT.

The S-Curve and its Significance in the Practical Heat Treatment of Steel, by A. L. Simmons. (*The Australasian Engineer, Science Sheet, 7th June, 1944, 18pp., 23 figs.*).

The shortcomings of the iron-carbon equilibrium diagram with regard to the practical heat treatment of steel are discussed. S-curves are introduced with details on their method of construction, and their relation to cooling curves and hardenability. It is shown how variables such as analysis and grain size influence the shape of S-curves, and the modern interpretation of the martensite region is described. The continuous cooling S-curve is dealt with briefly, and this is followed by detailed discussion of various practical treatments, such as spheroidizing, annealing, normalizing, austempering, martempering and hardening, in their relationship to various regions of the S-curve. In conclusion it is pointed out how intelligent use of S-curves enables a fairly accurate prediction for designing a heat-treatment to meet any normal requirement.

Merits of Salt Baths and Air Furnaces for Heat-Treating Aluminium Alloy Parts, by J. Snider. (*Automotive and Aviation Ind., 1st March, 1944, Vol. 90, No. 5, 1 p.*).

Author (Goodyear Aircraft Corp.) outlines advantages and disadvantages for different Al parts used in aircraft industry. Suggests salt baths for processing formed parts such as ribs and long extrusions; air furnaces for heat treatment of small parts such as gussets and short extrusions.

(*Communicated by the British Non-Ferrous Metals Research Association*).

ADMINISTRATION AND ACCOUNTING.

Production Control in an Engineering Factory, by M. L. Yates, (*Mechanical World, 28th July, 4th, 11th, 18th, 25th August, 1944, Vol. 116, Vols. 3004, 3006, 3008, 9 pp., 12 figs.*).

A series of articles dealing with some aspects of production and material control in an engineering factory. Material lists and their compilation. General information sheets. Planning from material lists. Stock control, the institution of stocks and recording material receipts and disbursements. Checking material requirements and ordering material. Stock control routine for castings. Manufacturing instructions. Production to schedule. Stores delivery notes. Issue of material for production. Operation tickets. Application of the tag system to the control of assemblies. Location cards Collection of parts required. Shortage sheets. Assembly control.

Planning as a Tool of Effective Administration, by W. Metcalf. (*Machinery-Lloyd, 5th August, 1944, Vol. XVI, No. 16, 4 pp., 4 figs.*).

Wider interpretation than merely the control of production. The four fundamentals are : (1) Machine loading ; use of a bar chart by production, costs, sales and estimating departments. (2) Material control ; for order requirements, amount in stock, amount on order, and amount allocated to current orders. (3) Scheduling ; splitting up the plant load into its operational elements and time elements. (4) Progress ; objective control to ensure that the order is maintained as closely as possible on the course and to the time schedule originally planned for it. Examples of : load chart, material control record, machine loading schedule and progress list.

Cost Control, by J. P. Wilson. (*Aircraft Production, August, 1944, Vol. VI, No. 70, 5 pp., 4 figs.*).

The application of standard costs in the aircraft industry. Component costing. Direct analysis costing. Complications. Functions of cost accounting. Outline of two possible plans.

Production Control. (*Aircraft Production, August, 1944, Vol. VI, No. 70, 1 p.*).

A list of suitable literature, with comments.

ELECTRICAL ENGINEERING.

The Applications of Electronic Control in the Steel Industry, by E. H. Vedder. (*Sheet Metal Industries, August, 1944, Vol. 20, No. 208, 3 pp., 4 figs.*).

Part I. This series describes the uses of electronic control for motor control, resistance welding control, photo-electric controls.

EMPLOYEES AND APPRENTICES.

Ford Trade School, Dagenham, by C. Attwood. (*Industrial Welfare, July—August, 1944, Vol. XXVI, No. 295, 2 pp., 2 figs.*).

School founded in 1930. 108 boys and staff of ten instructors, a shop, foreman, and two class teachers. About thirty times as many boys apply for admission as can be accepted. Boys selected exclusively from local elementary schools, boys from secondary and technical schools being ineligible. Working conditions. Shop training scheme. The bulk of the work consists of the manufacture of tools, gauges, jigs, and experimental parts, the repair of clock indicators and other precision instruments, and many skilled miscellaneous jobs which would not well fit into the routine of other departments but form a useful service to the factory as a whole. Shop equipment valued at about £25,000. Value of the work produced about two thirds of the total cost of the school for wages, salaries and material, but excluding all overhead costs. Curriculum followed in class rooms. Recreation facilities.

Training Apprentices, by H. F. Plaut. (*Machine Shop Magazine, August, 1944, Vol. 5, No. 8, 6 pp., 10 figs.*).

Scheme of an establishment manufacturing form ground tools, form relieved milling cutters, gauges, small machine tools and optical instruments. Sources of supply of apprentices. Best age. Interviewing. Three weeks intensive training course before entering shops. Works school syllabus. Result of training. Training in the works. Outside schooling during training.

Cooperation through Education. (*Industrial Welfare, July-August, 1944, Vol. XXVI No. 295, 2 pp.*).

The Glacier Metal Company's educational scheme for employees. Education in internal administration. Industrial education by works visits. Foremanship. Technical lectures and discussions. Workers affairs. Upgrading classes. Planned discussion. Weekly news bulletin.

FOUNDRY, MOULDING AND CASTING.

Mechanised Foundries. (*Automobile Engineer, July 1944, Vol. XXXIV, No. 451, 4 pp., 5 figs.*).

A report recently issued by the mechanical development sub-committee of The Institute of British Foundrymen deals with the principal methods for each stage of material handling. It covers items under the following headings : the stock yard, stock yard to cupola, charging methods, mechanised sand system, bucket elevators, flat and troughed belt conveyors, scraper or push-plate conveyors, apron plate conveyors, moulds, roller track, overhead-chain conveyors, plate-type floor conveyors, and conveyor capacities and speeds.

(*The report also appeared in " The Engineer " for the 4th, 11th, and 18th, August*).

A Study of Moulding Methods for Production of Sound Castings, by F. G. Sefing. (*American Foundryman, April, 1944, Vol. 6, No. 4, 4 pp.*).

Principles and applications. Gate design ; position of gates and risers ; atmospheric pressure feeding ; riser connections ; use of chills or denseners ; venting mould cavities. Illustrations of castings (steel, cast iron, bronze and light metals).

(*Communicated by the British Non-Ferrous Metals Research Association*).

Inoculated Cast Iron, by H. P. Hughes and W. Spenceley. (*Mechanical World, 11th August, 1944, Vol. 116, No. 3006, 6 pp., 7 figs.*).

This abstract of a paper presented to the Institute of British Foundrymen describes the difficulty encountered with warping and a technique developed to overcome it by using inoculants. Complications encountered. Vibratory feeder for inoculants. Size and type of inoculant. Improved results shown by comparative mechanical properties of ordinary and inoculated cupola metal. Simpler melting practice by means of inoculation allowing reduction in number of irons used. Underlying theories of inoculation and the findings arrived at during this investigation. Examples of castings produced. Difficulties.

Cost of Meehanite Castings v. Welded Structures, by L. F. Williams. (*Machine Shop Magazine, August, 1944, Vol. 5, No. 8, 6 pp., 5 figs.*).

Progress publicity in welding technology and design compared with lack of publicity for foundry improvements. Experience of Cooper-Bessemer Corporation with cost and performance data on cast and welded components for large diesel engines.

Steel Castings for Aircraft. (*Aircraft Production, August, 1944, Vol. VI, No. 70, 3 pp., 8 figs.*).

Production of the undercarriage pivot bracket casting for the Hawker Typhoon fighter by Hadfields, Ltd. Moulding. Cores and assembly. Sand properties. Quality control.

The Mechanised Production of Aluminium Gravity Die-Castings for the Merlin Engine, by J. Vickers. (*Inst. Brit. Foundrymen, Paper No. 805, June, 1944, 27 pp.*).

Part I outlines work of the development department of the Rolls-Royce Company and gives an illustrated description of typical dies. Part II covers production, inspection and personnel (according to pay-roll 45% female workers). The alloys used in this die-casting foundry are : RR. 50., RR.434, B.S.S.L11, B.S.S.L11, + Mg, B.S.S.L33 and NA226.

(*Communicated by the British Non-Ferrous Metals Research Association*).

MACHINE ELEMENTS (BEARINGS).

The Lubrication of Plain Bearings, by E. V. Paterson. (*Mechanical World, 25th August, 1944, Vol. 116, No. 3008, 5 pp., 11 figs.*).

Basic principles and their application to grooving of bearings. Theory of lubrication. Desirability of small bearing clearances and effect of surface finish. Effect of distortion of shaft. Self aligning bearings. Remedying deflection and end leakage. Correct point of introducing oil. Dangers of oil grooves. Oil grooving considerably overdone in the past. Chamfering. Chamfering for reversal of pressure. Reduction of end leakage losses. Force feed systems.

Jewel Bearings for Aircraft Instruments, by P. Grodzinski, and W. Stern. (*Aircraft Production, August, 1944, Vol. VI, No. 70, 4 pp., 14 figs.*).

Manufacturing methods employed in the U.S.A. by the Hamilton Watch Company. Splitting and sawing operations. Sawing machines. Face grinding. Rondelling machine. Drilling with multiple drilling machine. "Opening." Shaping the hole profile. Rumbling equipment. Countersinking. Making convex faces. Polishing. Surface quality. Useful series of illustrations.

Contribution to the Theory and Practice of Bearings, by Henri Brillie. (*Power Transmission, 15th August, 1944, Vol. 13, No. 151, 7 pp., 3 figs.*).

Problem presented by bearings. Fluid friction. Turbulent and streamline flow. Constant value of the coefficient of viscosity. Influence of the limited width of the film. Oil losses. Film stability. Conditions for calculation. General principles. The elementary theory of viscosity. The hypothesis of the speed parabola. Characteristic curves. Films of uniform thickness between parallel surfaces. Elementary films of slight eccentricity. Elementary films of any cross-section. Partial films. Nozzles. The complete film. Theoretical and experimental investigations by other workers. Conclusions.

Journal and Thrust Bearings : the Performance of Oil Rings, by E. Baildon. (*Power Transmission, 15th August, 1944, Vol. 13, No. 151, 4 pp., 4 figs.*).

The article deals with : propulsion of rings, relationship between journal and ring speeds, oil transfer, proportions if ring and journal and cross-section of ring, material, collecting groove, oil ring guiding, scraping devices, special ring sections and viscosity.

MACHINING AND MACHINE TOOLS.

The Production of the Wickman 5-Spindle Automatic. (*Machinery, 3rd, 10th, 17th, August, 1944, Vol. 65, Nos. 1660, 1661, 1662, 21 pp., 30 figs.*).

Description of machine. Special layout adopted for the shops in which

the 5-spindle automatic is made. Operations on castings. Weathering and annealing practice. Planning and plano-milling operations with carbides. Set ups for milling and boring operations. Grinding 90% of all faces. Inspection. Spindle drum. Description and machining operations. Roughing and heat treatment. Boring and reaming. Spindle bearing holes. Grinding the location pad. Checking the drum for indexing. Special cam-milling and grinding machine. Centre block. Machining operations. Special indexing fixtures for finish-milling and grinding the five faces. Coloured micrometer system. Assembly and testing operations. Unit assembly. Running-in fixture for the spindle-drum assembly. Alignment test sheet filled in by the inspectors in respect of each machine built. Demonstration bay test sheet for issue to the customer. The tests include ; spindle drum machining, and assembly inspections, spindle drum divide inspections, centre guide and spindles parallel, tests on centre guide and beam facing ; cross-slides and spindles square, and pentagonal block and independent slides. Main assembly. Details of slide operation. Running tests.

Bailey Meter Contour Control. (*The Machinist, 5th August, 1944, Vol. 88, No. 17, 2 pp., 4 figs.*).

Equipment claimed to repeat to 0.0002 in. and give smooth finish. In one setting of the tool, all diameters, round corners, square shoulders, slow and fast tapers, and radii that may be called for on a workpiece can be machined upon a lathe or vertical boring mill equipped with the contour control. Description of pneumatic operating gear.

Securing Fine Surfaces by Grinding, by H. J. Wills. (*Machinery, 10th August, 1944, Vol. 65, No. 1661, 4 pp., 3 figs.*).

The application of dressing tools. General principles. Grinding wheels must be balanced before and after truing. Elimination of spiral lines on the work. Method of dressing with an abrasive wheel. Wet and dry dressing. Care of dressing wheel. Technique of diamond dressing. Turning diamonds. Location of diamond. Traverse rates. Dressing for the finest precision grinding.

Securing Fine Surfaces, by H. J. Wills and H. J. Ingram. (*Machinery, 24th August, 1944, Vol. 65, No. 1663, 3 pp.*).

It is possible to grind with an ordinary grinding wheel to tolerances as close as 0.00005 inch for diameter and 0.00005 inch for roundness and straightness, and obtain a surface quality of from 0.4 to 0.7 μ-inch r.m.s., but not on a mass-production basis. On a production basis, it is possible to grind to a surface quality of from 2 to 5 μ-inches r.m.s., within a dimensional accuracy of 0.0001 to 0.0005 inch. Lapping may be resorted to for the purposes of securing minute accuracy of dimension, great surface smoothness, and correctness of shape and it may be more economical to use lapping for the final operation, than grinding alone even though the latter can give the required surface. Parts which are commonly lapped are listed and the principles in lapping described. The following are then considered : pressures used in lapping, materials for laps and selection of abrasives, and selection of lapping vehicle.

Momentum in Carbide Milling of Steel, by E. O. Lowell. (*The Engineer, 4th August, 1944, Vol. CLXXVIII, No. 4621, 1 p.*).

The need for momentum adaption of existing machines. Heavier chip load a very important factor in increased cutter life. Reduction in power. Means of imparting momentum to the cutting operation by the use of increased mass. Results with a 110 lb. flywheel.

Fine Engraving Instrument. (*Industrial Diamond Review, August, 1944, Vol. 4, No. 55, 2 pp., 3 figs.*).

Description of a German engraving machine used to produce workpieces with microscopically minute figures as required in precision and optical engineering, by scratching the marks into the material or etching ground with either a steel needle or a diamond.

CHIPLESS MACHINING.

The Pressing of Sheet Metal, by H. W. Swift. (*Sheet Metal Industries, August, 1944, Vol. 20, No, 208, 4 pp., 7 figs.*).

Section V. Trimming and finishing. Press capacity of hydraulic and crank presses. Danger of overload. Constant speed operation.

The Production of Aircraft Stampings, by J. A. Oates. (*Aircraft Production, August, 1944, Vol. VI, No. 70, 7 pp., 17 figs.*).

Part I. A review of the laboratory control and manufacturing methods of High Duty Alloys, Ltd. Large-scale research and development activities and maintenance of high quality by strict laboratory control of all manufacturing processes. Aircraft stampings in the Hiduminium RR 56 series of alloys. Their properties and heat treatment. Laboratory control. Colorimeteric analysis. Chemical laboratories. Electro-chemical analysis. Sequence of manufacture. Spectrographic analysis. Stamp shop. Die lubricant. Etching.

Press Tools for Mica, by P. Wise. (*Machinery, 24th August, 1944, Vol. 65, No. 1663, 3 pp., 2 figs.*).

Pure mica as a material for working in press tools, rates high among those that are difficult to handle. The article discusses the relevant properties of mica and gives general principles which must be observed. The irregularity of the shapes in which the sheets are obtained has an important bearing on the design of tools ; guides and stops are impracticable, hence tools must be of the combination type. It has been found possible to use reversed combination tools quite successfully on mica work, and a tool of this design is described with details of its construction and operation. For long runs, there seems to be a case for tools with tungsten carbide inserts.

MANUFACTURING METHODS.

Motion Study and Time Study—Their Place in Industry, by W. F. Walker. (*Machine Shop Magazine, July and August, 1944, Vol. 5, Nos. 7 and 8. 18 pp., 3 figs.*).

Taking the observations. Fatigue due to noisy workshops. Bad postures and poor shop atmosphere and lighting. Application of motion and time study to material handling and tools. Training of labour. Job analysis. Effort rating and its determination. Time studies and fatigue. Advantages and disadvantages of the use of synthetic data from previous studies. Examples of synthetic data. The personnel of the motion and time study department. Studies in other departments. Nomograms to calculate the time required to complete a cutting operation. The teaching of motion and time study. Summing up.

The Brisch System of Decimal Classification in Production, by Rolt Hammond. (*The Engineer, 11th August, 1944, Vol. CLXXVIII, No. 4622, 1 p.*).

A brief description of a system evolved by a Polish engineer and applied successfully on the Continent.

MATERIALS AND MATERIAL TESTING.

Physical and Mechanical Properties of Diamond and Similar Substances. (*Industrial Diamond Review, Data Sheet, No. 6, (New Series), August, 1944, Vol. 4, No. 45,*).

Included are : melting point, refractive index and dispersion, scratch and absolute hardness, etc. References and explanatory notes.

RESEARCH.

Problems of Scientific and Industrial Research : A Statement. (*Brochure, April, 1944, 63 pp.*).

A statement which is the outcome of two conferences. The 92 signatories are nearly all scientists, industrialists, ecomonists, etc., of eminence. It is offered as a contribution to current discussions of post-war economic and educational policy, and surveys the subject from many angles, including that of the Industrial Research Associations.

(*Communicated by the British Non-Ferrous Metals Research Association*).

Science and Industry, by Lord Riverdale, A. P. M. Fleming, A. McCance, Sir E. V. Appleton. (*Brochure, 1944, 63 pp.*).

Four addresses given to the Manchester Chamber of Commerce, March-April, 1944. Lord Riverdale (pp. 3-14) dealt with " Research and Industry : The Need, the Ways and the Means " ; Dr. A. P. M. Fleming (pp. 19-28) with " Research Workers : Their Education and Their Place in Industry " ; Dr. A. McCance (pp. 33-42) with " The application of Research " ; and Sir E. V. Appleton (pp. 47-59) with " Fundamental Research : Its Practical Importance."

(*Communicated by the British Non-Ferrous Metals Research Association*).

The Organisation of Research, by A. Parker. (*Journal of the Institute of Fuel, June, 1944, Vol. 17, No. 96, 2 pp.*).

Characterises organisation of research in universities and colleges ; special research institutes ; individual industrial undertakings ; co-operative industrial undertakings ; co-operative industrial reserach. The Department of Scientific and Industrial Research and the Fuel Research Station. Selection of research staff.

Increasing Production Efficiency with Tool Life Tests, by L. L. Thill, and E. B. Fremon. (*The Tool Engineer, (U.S.A.), July, 1944, Vol. XIV, No. 1, 1 p.*).

An unusual report on the results of a large-scale tool life test conducted on automatic screw machines in actual production. Stressed by the authors is the fact that under identical test conditions, wide variations in results occur. A method is illustrated for determining how many tool changes are necessary to secure data of desired accuracy. Tests on standardized parts. Tool life tests of a run on 38 automatic screw machines over a period of 30 shifts of eight hours each during ten days. Test set up. The term " tool life " as used here means the number of pieces run before a change of one or more tools was required because of poor finish or inaccuraacy of dimension in the finished parts. Extremely wide variations occured in the tool life figures from 89 pieces in one machine to 18,900 pieces in another. Analysis of test data. Use of results in reducing tool failures.

Fabrication of Tractor Wheels, by N. B. Cave. (*Welding, August, 1944, Vol. XII, No. 9, 2 pp., 4 figs.*).

Utilisation of arc and flash butt welding for (a) rim joints (flash) and (b) centre disc lugs and speeds (arc). Use of jig.

10-20 Ton Welding Manipulator. (*The Engineer, 4th August, 1944, Vol. CLXXVIII, No. 4621, 2 pp., 2 figs.*).

Description of a motor-controlled manipulator, designed specially for marine engine components weighing up to 20 tons.

Welding Processes in Automobile Production, by J. P. Blundell. (*Sheet Metal Industries, August, 1944, Vol. 20, No. 208, 10 pp., 19 figs.*).

Part II. Testing for pressure seam welding. Flash welding process. Rear axle assembly. Bogie torque cross tube and back to quarter panel assembly. Metallic-arc welding. Plant and electrodes. Application to body frames and wings.

Spot Welding on the "Lancaster." (*Welding, August, 1944, Vol. XII, No. 9, 9 pp., 10 figs.*).

The advantages of spot welding as compared with riveting. Difficulties inherent in the welding of light alloys, and the necessity for special equipments giving accurate control of a very high current for a short time. The equipment used on Lancaster aircraft components fitted with programme control Ignitron panels. The elimination of variables. Electrode tip. Design for different jobs. Tip maintenance including cleaning and re-machining. Cleaning of material with an acid paste etch. Inspection and testing. Routine for testing of shear specimens and examination of micro-sections. Production methods for tanks, panels, fairings, etc.

The Spot Welding of Light Alloys, by R. F. Tylecote. (*Welding, June and July, 1944, Vol. XII, No. 7 and 8, 14 pp., 11 figs.*).

Part I. Process now applied to all types of wrought light alloys. Machines and methods. Timers. The four cycles of operation in use. Current. Time and pressure effects. Other variables. Surface preparation by pickling or mechanical methods. Electrode design, cooling and cleaning.

Part II. Refrigerated cooling of the electrode. Strength properties in shear for tension and tearing and for fatigue resistance. Cold working. Corrosion liability. Metallurgical properties indicated by macro- and micro-examination. The design of joints.

Flash-Butt Welding. Parts I-III, by J. H. Cooper, J. J. Riley, J. C. Barrett. (*Iron Age, 13th, 20th, 27th, April, 1944, Vol. 153, Nos. 15, 16, and 17, 6 pp.*).

Part I discusses the basic principles of flash-butt welding under the headings flashing; energy input; preheating including differential preheating; welding heat; upset and upset force; welding suitability factor; upsetting force and physical properties; upsetting current; extensions from dies; and alignment of work. Part II deals with design for flash-butt welding; removal of flash and upset; surface preparation of the work; back-up and locating fixtures; and physical testing of welds. Tables and diagrams summarise the recommendations made. Part III. discusses metallurgical changes in and around a flash-weld, and means of controlling them. Defects are illustrated, the causes indicated and remedies proposed. Bibliography of 11 references.

(*Communicated by the British Non-Ferrous Metals Research Association*).

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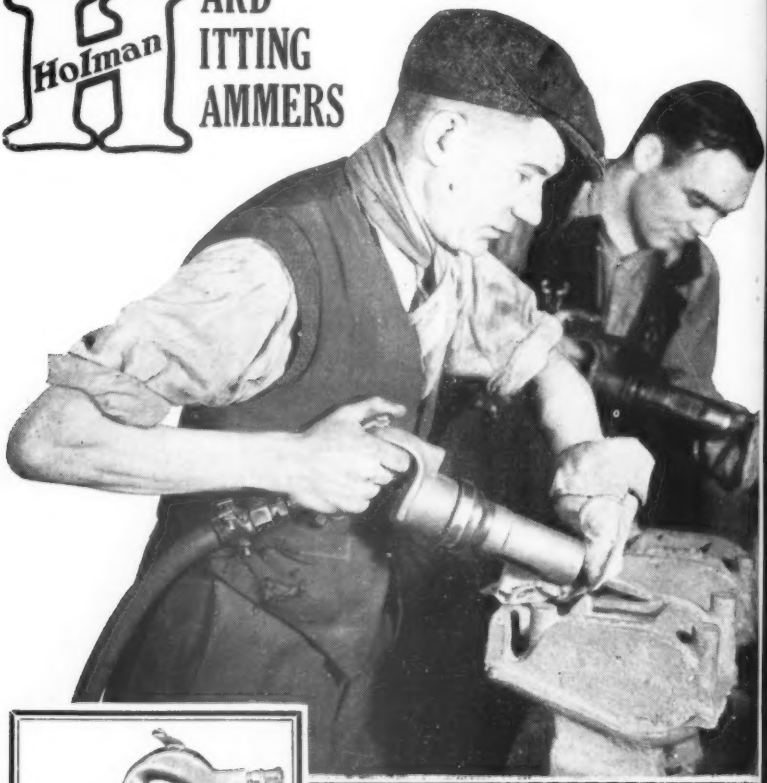

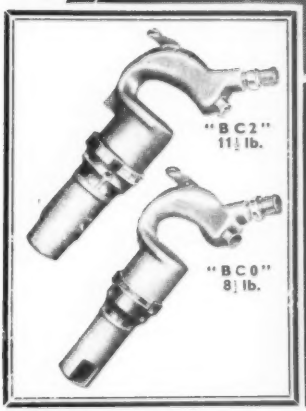

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